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THE APRIL SCIENTIFIC MONTHLY

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THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

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THE SCIENTIFIC MONTHLY

APRIL, 1936

MODERN ENERGY SUPPLIES

By Dr. GUSTAV EGLOFF

DIRECTOR OF RESEARCH, UNIVERSAL OIL PRODUCTS COMPANY, CHICAGO, ILLINOIS

PROGRESS of mankind through the ages has been measured by his increasing ability to utilize energy outside himself to do his work. This is true to-day, although it may seem that man has so much power at his command that at times it dislocates industry, causing unemployment. This, however, is no indictment of power itself; it is merely an ironic manifestation of our temporary inability to use it properly.

Since power is the mainspring of human progress, it is well to consider its sources. How long will they last, and how can we make the best use of them? The primary source of energy is the sun, and our most important power sources are composed of organic material which was grown in the sunlight of past ages and is now buried in the earth, where it has been converted into coal, oil, gas, peat and oil shale in the heat and pressure of nature's underground laboratories.

There can be no question that there are energy sources potentially available for man's every need for thousands of years at the present rate of consumption. The sources now used by man in the order of importance are: coal, oil, water power, natural gas, wood, man, animal and wind, with traces of peat, oil shale, power alcohol, internal heat of the earth, direct solar energy and future sources of energy such as tide power and differential in sea-water temperature.

COAL

Before coal was used to a great extent as a heating unit, the forests of many countries suffered and were practically denuded in order to furnish fuel and charcoal for the fast-growing iron and steel industry. The early history of coal as used by man is unknown. Scattered throughout Greek and Roman history there are references to the use of "stones that burn." Remains of coal fires were found in Britain by the explorers of the early Roman camp sites. It is in the twelfth and thirteenth centuries that we begin to find notice being given to the use of coal which was either washed up on shore by waves or found in outcroppings in the hills. Immediately following these discoveries an era of coal utilization ensued which was marked by the digging of holes in the ground to mine the coal.

As coal became highly competitive with wood as a fuel in England in the early centuries of its extensive use, it was found that burning coal was against the laws of God and man, and some men went to jail for using it.

Coal is available as bituminous, semi-bituminous, lignite and anthracite. The earth contains over 7,400 billion tons, of which mankind is using about 1.3 billion

tons a year. At present rates of consumption, coal is available for man's needs to cover a period of the order of 6,000 years.

Coal as such is not of much importance until it gives up its energy in the form of power. The heat from coal is used to furnish electrical and steam power for driving locomotives, ships and turbines. Other useful products are obtained from coal, under special heating conditions, such as gas, coke, motor fuel, pitch, asphalt and other substances used in the chemical and plastic industries. In order to generate one horse-power of electrical energy, in 1920 four pounds of coal were used; in 1935, only one pound of coal per horse-power was required, and improvements are still being made to cut the quantity of coal needed per horse-power of energy output.

Of the total energy used in the United States last year, 48 per cent. came from coal.

One of the important uses of coal is to convert it into gas, and yearly the gas-making industry produces over 500 billion cubic feet of gas in the United States. At the present time, coal is shipped by cars to the different cities where it is converted into gas, liquid and coke; and coke in turn converted into water gas or carbon monoxide and hydrogen or used for metallurgical purposes. A more economical method of producing gas for heating and lighting purposes from coal would be to produce the gas at the mine and then pipe it to consuming centers of population. This would bring about an enormous saving in the cost of gas or energy production and eliminate the transportation of coal, relatively high in ash and water having no heating value, and much of the soot of cities, which is so detrimental to society. Gas production at the coal mine is not being carried out in the United States; however, in the Ruhr district of Germany, gas is produced at the mine and then transported by pipe line hundreds of miles for industrial and home use. In some countries the coal gas is compressed into cylinders and used as motor fuel and sold much like gasoline at filling stations.

A development that is going on in Germany and England for the better utilization of coal is to convert it into gasoline and other oils by the hydrogenation process. Two commercial plants, one in England, another in Germany, are in operation to liquefy coal into oil under hydrogen pressure of the order of 4,000 pounds per square inch and temperature of 900° F. It is reported that every ton of coal processed yields five barrels of gasoline or oil.

Another important catalytic process developed in Germany is the production of gasoline, kerosene, gas oil, waxes and lubricating oils through the reaction of water gas or carbon monoxide and hydrogen derived from coal and water. The oils produced can be converted into high octane motor fuel to the extent of 85 per cent. of the oil by the cracking process. These two processes are relatively expensive to operate at the present time and are commercial, due to governmental subsidy. The cost of producing motor fuel is of the order of more than four times that of gasoline produced from petroleum.

It is interesting to note that there was a flourishing coal-carbonizing industry in the United States composed of 56 plants in 1859, which were forerunners of the oil industry, to produce kerosene and lubricating oil. In that year the Drake oil well came in, and coal carbonization for kerosene and lubricant production died out. Some of the distillation plants were used in the oil industry to fractionate Pennsylvania crude oil. History may repeat itself, if and when our crude oil supplies fail, so that our

refineries will operate on oils from coal. Whatever change takes place will be a transition and not abrupt.

From the world's store of coal of 7,400 billion tons we can produce by the hydrogenation and cracking process enough oil to supply world needs for over 24,000 years, at the present yearly requirements of 1.5 billion barrels of crude oil.

Oil

To-day we know that hydrocarbons are widely distributed through the earth, whether they be coal, petroleum, natural gas, oil shale or peat. Petroleum is particularly wide-spread, despite the general belief that there is a very limited quantity available for future generations. From the geographic standpoint, petroleum may be located in any part of the world. For example, it has been found in the Arctic Circle, in the jungles of Colombia and Borneo on the Equator, and in the temperate zone of the United States. Oil has been located high on the slopes of the Andes in Peru, 13,000 feet above sea-level, and on the ocean floor of the Pacific in California, and in the desert land of the San Joaquin Valley. As an illustration of the diverse places where petroleum occurs, one need but refer to Chicago. True, it would be expensive to recover, but Chicago is built upon a deposit of dolomitic limestone, which contains for each square mile 7,500,000 barrels of oil—therefore, the 200 square mile area in Chicago contains 1.5 billion barrels of crude oil.

In the last year alone more than 40 new oil pools were discovered, which has added over 1,250,000,000 barrels of crude oil to our reserves.

In the first six months of 1935 over 10,000 new wells were drilled, of which about 70 per cent. were oil producers, with 6 per cent. as gas wells and the balance dry holes. During the ten previous years the average oil producers represented 61 per cent. of the wells drilled, a striking illustration of the effect of science upon oil location.

Crude oil is the second largest energy source in the world. It is being produced at the rate of 1.5 billion barrels a year and ranges as it flows from the wells from an almost pure gasoline to a solid at ordinary temperature. Crude oil shows colors from white to black and also of the rainbow. The odors of crude oil vary widely from the perfume odor of sandalwood and pungent camphor of the sickroom to the vile odors that even put a self-respecting skunk in the shade.

Since the foundation of the oil industry in the world, about 26 billion barrels of crude oil have been produced. This volume of oil would not fill a hole in the ground a mile deep and a mile square. Geologists estimated in January, 1934, that over 13 billion barrels of crude oil are available by present producing methods in the United States, or a supply for fifteen years. Between 38 and 115 billion barrels of crude oil are left in the earth and not recoverable by present methods used in the United States. An average of these volumes is a supply of oil for about 85 years if one would mine the oil in a similar way to coal as they do in Alsace Lorraine, France, and Hanover, Germany. Moreover, the earth itself may be used as a giant still. By burning a part of the oil in the sand, distillation of the oil would bring the vapors to the earth's surface where they may be fractionally condensed to the products desired. Jesse A. Dubbs, an American, invented this method over 40 years ago, and recently, Russian oil technologists have carried out the process in their country with some order of success.

The oil industry is producing crude oil at the rate of a billion and a half barrels a year to supply not only the 35,000,000 motor cars in the world with gasoline and lubricants, but also the manifold

energy requirements of society. The oil industry is honeycombed with technologists from every branch of science, in order to improve oil location, drilling, storage, transportation in over 100,000 miles of pipe line and refining into finished products.

One of the greatest conserving forces in the world is the cracking process, which converts oils that do not contain any gasoline as such, by the application of temperatures of 950° F. and pressures of about 300 pounds per square inch, into high antiknock motor fuel with yields from 60 to 80 per cent. By saving crude oil, as a natural consequence, cracking has decreased the cost of locating oil, drilling, pipe lines, storage and refining facilities. This is estimated as a saving of $1,300,000,000 capital investment on these items, in addition to the yearly value of the crude oil thus conserved.

If refiners had been forced to produce without cracking the 18 billion gallons of gasoline needed to operate the 25 million motor cars in the United States, the quantity of crude oil required to produce this amount would have been double that actually refined, *i.e.*, approximately 900 million more barrels would have been required to satisfy our motor fuel needs.

Petroleum through the years has been an increasing competitor of coal as an energy producer. It now represents over 22 per cent. of the total energy used in the United States. About 45 per cent. of the total crude oil refined in the United States during 1934 was gasoline which was used in our motor cars, airplanes, motor boats and tractor engines. The quality of gasoline has been steadily improved through the years; a relatively recent revolutionary discovery in the oil industry being the production of polymerized gasoline. This motor fuel comes from the gas produced by the cracking process, which heretofore has been used as a fuel under stills or boilers. There is available yearly 300 billion cubic feet of cracked gas having a potential of over 1,000,000,000 gallons of 81 octane gasoline. Polymerized gasoline upon hydrogenation will produce 100 octane gasoline and make it possible for airplanes to hurtle through the air at the rate of over 500 miles an hour; thus the trip from New York to Chicago in less than two hours can be accomplished.

With thousands of geologists, chemists, physicists and engineers searching for oil, the amazing success of collective effort in locating new fields and drilling to depths of over two miles with but 2° off the vertical and finding oil, augurs well for the future of the oil industry in that we will have ample supplies of oil for our every need for more than a century.

Water Power

One of the oldest sources of energy for man has been the waterfall. Since the invention of the water wheel for capturing the power of running water by some ancient Egyptian on the banks of the Nile, the refinements and uses of the present water wheel would render it unrecognizable to the inventor. The first water wheels were probably used for grinding corn. At the present time our water turbines have reached a 94 per cent. efficiency, which is the best power-producing machine that man has so far achieved. In the United States to-day the percentage of energy derived from waterfalls is 8.0 per cent. of the total used.

The total potential horse-power from waterfalls in the United States has been approximately estimated to be 127 trillion horse-power yearly and we are actually using 42 trillion.

Water, as far as we know, is a perpetual source of potential power, and may come into its full utility at a distant date when other energy sources may be exhausted.

The difficulty in using much of the

water power available lies in the fact that it is on the fringes or remote from consuming areas. General belief is that all man has to do is to place some wheels in the stream of water and, lo and behold, he has cheap energy. Not so, when one considers the high installation cost and electrical transmission over distances to large consuming communities and the incident loss of energy during its transmission. Water power as a source of energy in many areas is more expensive than that derived through the generation of steam power by coal, oil or natural gas.

Giant undertakings by man are represented in the Boulder Dam project, the Norris Dam and the one proposing the use of the tides at Passamaquoddy, Maine. This intends utilizing a tide frontal wave coming in at a height of 28 feet. This project, sponsored by the United States Government, will cost about $36,000,000. It will have a daily capacity of 200,000 horse-power from the energy of one of the world's highest tides, and furnish electrical energy for homes, farms and industry by tapping the gigantic and inexhaustible force of the ocean. This ebb and flow of tides has been an urge to man's inventive genius for centuries to convert it into useful work. Many projects have been advanced from time to time to harness tides such as those in the Chinese River at Tsien Tang, Severn River in England, estimated to be able to deliver 1,250,000 horse-power per day, the Coast of Brittany in France and the tidal basin at Passamaquoddy. The United States is the only country actually putting in a plant for the generation of electrical energy by tidal means.

An ingenious proposal has been made by Dr. Georges Claude, who has experimented with a semi-commercial plant in Cuba to utilize the warm water layer on top of the ocean by passing it into a vacuum, thereby generating steam and using the cold water layer of the ocean as the cooling fluid to condense the steam. Thermodynamically, this is a sound principle, but only time will tell whether it will be economical and competitive with other sources of energy. However, from a potential energy source, utilization of temperature differential in waters of the earth reaches astronomical figures.

Natural Gas

Natural gas is not alone produced as such but also accompanies crude oil. In progressive oil fields where it is possible, the excess gas is pumped back into the oil sand to maintain pressure and lengthen the life of the field.

Natural gas is one of the ideal energy-producers, due to its composition of methane and ethane hydrocarbons, which lend themselves particularly to usefulness in gas engines, steam production and industrial and household uses because of its high heating value per unit volume. Natural gas represents 8 per cent. of the total energy used in the United States. Gas is readily transportable, and thousands of miles of pipe lines radiate from the gas fields, such as the Panhandle of Texas, Kettleman Hills in California, Oklahoma, Louisiana and Pennsylvania. A pipe line snakes its way clear from Texas to Chicago. Vast gas fields are used to supply not alone Chicago with energy, but also other cities, such as St. Louis. The volume of natural gas delivered to Chicago from Texas is about 100 million cubic feet per day. It is estimated that the Panhandle of Texas alone could supply the needs of their clients for over 200 years.

Outside of the United States very little natural gas is being used; however, there are vast volumes potentially available in different parts of the world. In the Persian oil fields, where there are no industries, something like a billion cubic feet

of natural gas is shot into the atmosphere daily. Vast quantities of natural gas also escape into the atmosphere in different oil fields of the world where no ready markets are available.

Natural gas is being produced at the rate of over 1.6 trillion cubic feet a year in the United States. The North American supply in present fields is estimated at 75 trillion cubic feet—or enough for about 50 years at present consumption rates.

Wood

History advises us that wood was the first heating and power source man ever utilized. A little over 300 years ago the early settlers of the United States were just beginning to use the forests for their energy supplies from the 900,000,000 acres of forest. Wood is still an important source of energy, as it represents over 7 per cent. of the total utilized in the United States during 1934. The percentage of wood consumption for the world as an energy producer is much higher than in the United States. Reliable data are lacking. However, in some countries, such as Roumania, which is a large oil-producing country, one can note that the steam locomotives used in that country are fired by wood, coal and oil. The wood-burning locomotives are used to keep the wood-choppers of Roumania employed.

In some parts of the world, wood is used to run motor cars and busses by converting it into gas. Italy has a number of passenger busses operating between Milan and Rome on gases derived from carbonized wood.

Due to modern research, wood can be carbonized into 40 gallons of tar per ton. This tar by the cracking process can be converted into 26 per cent. of motor fuel and 21 per cent. of Diesel oil, the balance being coke and fuel gas.

With heavy reforestation in the United States, we can in time build up enormous resources of energy, which can be utilized when other sources diminish or disappear.

Man and Animal

Man started out in this world with his own energy, which amounted to one eighth of a horse-power per day. It is not certain how long he relied upon his own energy. The first that he used outside of himself was probably the heat from wood. Then he corralled the jackasses around him, either in the form of some of his neighbors or the animals that he caught, and put them to work.

Man and animal power is not great when measured in terms of power used through the world from other sources. However, it is still a very substantial portion of the total, for in the United States it represents 5 per cent. of the energy used. It is much greater in other countries backward as far as the machine age is concerned. From the 2 billion people in the world and 85 million horses, mules and burros, in addition to an unknown number of yaks, water buffalo, elephants, dogs, camels, reindeer and oxen, the potential energy in horse-power per year for man and beast must be over 110 billion.

Wind

Man has used wind as a power source for years on end to the very present. Sailing ships and windmills have been the means of utilizing wind for his needs. Of the total energy used in the United States last year 1 per cent. was derived from the wind. Wind, as any one living in Chicago knows, is not very satisfactory from an industrial standpoint, since man has not yet been able to command the time for it to blow, outside of himself. However, some adaptations of the windmill have been made in recent years to generate electrical energy or hoist water for farm use.

In France and Denmark, countries low in potential power sources, the development of the windmill for electric power was given a strong impetus by the world war. The French windmills are built for strong winds, and there are some in operation capable of giving 300 horsepower output.

In 1932, a German engineer set forth the formidable plan of harnessing high altitude winds by building 1,400 foot towers to support vanes 524 feet in diameter. A unit costing $1,000,000 would supply the electrical needs of a city of 100,000 at a cost comparing favorably with steam and water power.

Another type of development which has been tried with varying degrees of success is the rotor tower. The driving force to the revolving towers is furnished by eddying wind currents. In 1926 Flettner applied this principle to the propulsion of a ship. The Flettner rotor ship towers were 60 feet high and 10 feet in diameter. The towers rotated at about 100 revolutions per minute, propelling the ship in the direction desired. Some rotors were installed in New Jersey to generate electrical power. The rotor power plant consisted of a number of large cylinders 90 feet high and 22 feet in diameter. This installation was calculated to produce 1,600 horse-power per day.

The energy potential available from the wind is enormous, but no really economic method has been devised so far to use it. Whenever the urge is great enough to utilize wind as a continuous source of energy, man's inventive faculty will undoubtedly find the way.

Peat

Peat has been used as fuel probably since the dawn of civilization. Its use was recorded by Latin writers during the conquest of northern and western Europe by the Romans. It has been burned for hundreds of years in Russia, Ireland, Finland, Denmark, Sweden, Holland and Germany, and also in the pioneer days in the United States.

The areas of peat land in various parts of the world are enormous in their extent and in the amount of peat which they contain. It is estimated that the peat deposits of the world are over 200 billion tons, of which Russia has about 65, Finland 38 and the United States 14 billion. The amount of energy produced from peat in the world is but a trace of the world's energy production.

Peat as nature produced it contains water and it is necessary to dry before use. By low-temperature carbonization, the world potential of peat tar is over 100 billion barrels, which can be converted by the cracking process into 35 per cent. motor fuel or a 75-year supply at the present rate of oil consumption.

Oil Shale

Oil shale deposits are located in many parts of the world. The principal ones on the American continents are those of the United States, Canada, Brazil, Argentina and Chile. They are also found in the British Isles, France, Jugo-Slavia, Spain, Sweden, Bulgaria, Germany, Italy, Switzerland, Esthonia and Russia. There are also considerable amounts of oil shales in Australia, China, Japan, Arabia and Syria.

The retorting of oil shale to produce oil, gas and coke is in commercial operation in France, Esthonia, Spain, Scotland, Australia and Manchuria. Oil production from shale is relatively expensive, and although a vast amount of work has been carried out in the United States endeavoring to find an economical process, none has survived because of the competition of coal and petroleum. The oil shale is mined, split into small pieces and put into retorts which are externally fired; the vapors from the shale are con-

densed and refined to marketable products.

A most ingenious oil shale plant operated for a number of years in Australia, which used the mountain of oil shale as a still. A horizontal shaft was drilled into the mountain, and a vertical shaft met the horizontal. A fire was started by the admittance of controlled quantities of air, the oil distilling out of the shale passing up through the mountain and into pipe connections at the top to condense the products. This is a cheap way of obtaining oil, but it threw so many men out of work, it is reported that the Australian Government stopped the process. There is no technical reason why this process is not a practical one and cheap to operate.

It is estimated that the United States has potentially available over 108 billion barrels of shale oil which can be converted into motor fuel, lubricants and other energy-producing products modern civilization calls for.

The total quantity of oil shale in the world is unknown. That it is huge is generally acknowledged. The world's potential shale oil production is estimated to be at least 300 billion barrels or 200 years' supply. By the use of the cracking process this oil would yield sufficient gasoline to operate all the motor cars in the world at the present time, for over four hundred years, with 180 trillion cubic feet of fuel gas and 11.3 billion tons of coke as by-products. The amount of shale oil produced in the world at the present time is insignificant as measured in terms of energy output.

Power Alcohol

Photosynthetic processes are the best means nature has of utilizing solar energy. Our society uses energy at a prodigious rate, and were it not for our vast stores of potential energy, civilization as operated to-day would be impossible. Much research has been done in recent years on power alcohol from crops; but if society had to depend upon alcohol and cellulose alone for power, it would require about 12 billion bushels of corn or its equivalent to produce enough alcohol to operate the motor cars in the United States alone. The volume of alcohol required would be about 30,000 million gallons, whereas the present production in the United States is 100 million. The enormous volume just given would not take care of the lubricants that our machines require. Alcohol can be converted, by a process called dehydration, into ethylene gas, which in turn can be catalytically polymerized into lubricants. To produce the volume of lubricants used yearly in the United States from corn would require over 2 billion bushels. Hence, 14 billion bushels of corn, or its equivalent, would be necessary to produce gasoline and lubricants for our energy requirements in motor cars and machines of society.

Power alcohol and alcohol lubricants would be at least five times more expensive to produce than those procured by present means from petroleum. Agriculture as a means of supplying modern society with its energy requirements for motor cars—which has been put forth by proponents as a relief for the economic ills of the farmer—would be tremendously expensive compared to present sources of supply. To rely on alcohol as an energy source would also be precarious, because of the uncertainty that is ever present in raising crops.

The amount of alcohol used as an energy source for the motor cars of the world is exceedingly small compared to other sources.

Direct Solar Energy

In considering the use of solar energy directly, man's necessities have not demanded a thorough investigation of the

possibilities. The methods by which solar energy may be used is well established in man's scheme of things, for it involves his food supply in the growth of plants, in the form of wood and in man's effort to utilize the sun as a direct source of power.

By direct utilization of the sun's heat, nature has the most efficient and yet the most baffling system ever worked before man's eyes. For all man's progress in finding out about nature, he has not yet been able to work out nature's most puzzling starch factory—chlorophyll—the green matter in living plants. During many ages the plants alone have been capable of utilizing the enormous floods of sunshine pouring upon the earth. Yet, that is but a small amount of the energy that has come to the earth from the sun.

Man has tried means of harnessing the sun's heat and utilizing it with more or less successful attempts ever since Archimedes used concentrated sun rays to set fire to the fleet of Marcellus at Syracuse. The chief difficulty in the use of direct solar energy for power has been due to storing of power until needed, and also to the intermittency with which the sun shines in most parts of the world. Sun power can be generated in boilers located in the desert on the border of arable land, and the power transmitted by electricity to consuming centers. A sun-power plant is in experimental use in Cairo, Egypt. The principle is the absorption and concentration of heat by means of parabolic mirrors which focus the heat on layers of water. The power from the plant was used to pump water for irrigation purposes.

If it were possible to convert into power all the solar energy that falls on the United States alone in the form of sunshine, it would furnish 7,000 trillion horse-power. At Mount Wilson Observatory, a 15-foot instrument with 30 lenses generates a temperature of 6000° C. In Russia efforts are being made to develop the practical harnessing of sun power.

Inventors and technologists have a real task ahead of them to work out economic methods of using the direct energy of the sun. However, we may rest assured that it can be worked out when the necessities of our social system demand it.

Internal Heat of the Earth

In many parts of the earth hot gases blow into the atmosphere in enormous volumes. They exude particularly in volcanic regions. The steaming crevices are caused by underground rivers coming in contact with volcanic fires. That this steam may be used for power has been demonstrated in Italy, where they generate 19,000 horse-power per day. In Sonoma County of California volcanic steam is used to generate electricity for local use. Other places not yet developed, but which have naturally occurring hot gases are the Valley of Ten Thousand Smokes in Alaska, Lassen Peak in California, Steamboat Springs near Reno, Nevada, and the Yellowstone Geyser Region.

Since nature has provided steam in these places from natural causes, one can assume that man could provide himself with power from the earth by drilling wells, either tapping hot gas sources or pumping water into the well, converting it into steam. It is well known that the temperature of the earth increases with increasing depth, the rate being less in older rocks than younger. The deepest well drilled by man so far is over two miles. The temperature gradient varies quite widely—some average 1° increase for every 65 feet in depth. A recent well drilled at Palestine, Texas, 9,000 feet

TABLE I
U. S. ENERGY PRODUCTION AND RESERVES

Energy source	Billion horse power production, 1934	Per cent. of total used in 1934	Reserves in million units	No. of years supply
(1) Coal	252,106	48.0	4,104,552 tons	10,000[1]
(2) Oil	117,572	22.5	10,000–13,250 bbls. known petroleum producible by present methods in known and proven fields.	11–15[2]
			38,526–115,736 bbls. petroleum remaining in producing formations of present known and producing oil fields after exhaustion of production by present methods.	44½–134
(3) Water Power	42,400	8.0	127,189 H.P.[3]	"Perpetual"
(4) Natural Gas	41,854	8.0	40,000	25[4]
(5) Wood	37,280	7.1	Enormous energy available if reforestation continues.	"Perpetual"
(6) Man and Animal	26,800	5.1		?
(7) Wind	6,990	1.3	Enormous	"Perpetual"
Total	525,002	100.0		

[1] Stanley Gill, "A Report on the Petroleum Industry in the United States," p. 297.
[2] *Ibid.*, p. 21.
[3] United States Power Survey, 1935, Interim Report.
[4] *Oil and Gas Journal*, March 14, 1935 (Valentin R. Garfias).

deep, showed a bottom temperature of 225° F. One deep well in the Kettleman Hills region produced 200° F. water at the rate of over 5,000 barrels a day instead of oil.

Can one say from these facts that our energy will ever be exhausted in any practical length of time?

ATOMIC ENERGY

From time to time some of the laboratories of the world have given forth the information that atomic energy will be available for man's use. As far as we now know, it requires more energy to crack atoms than the amount of energy given out. Hence we may not look upon atoms as a practical source of energy for man's requirements.

CONCLUSION

There are energy sources for man's every need for thousands of years, despite the fact that his demands have increased over forty fold in the last hundred years. Just how much energy will be required in a hundred, a thousand or a hundred thousand years hence is problematical. That it will be huge is certain.

Man has never failed in inventiveness to achieve the machines to use our vast potential sources to lessen society's labors. It is most likely that his future endeavors to lighten at least the physical load still further will meet with success.

The data of the energy consumption and supplies in the United States are shown in Table I.

PHYSICS, METAPHYSICS AND COMMON SENSE

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I. Physical Science in a Modern World

On this day in the twentieth century, when maladjustment seems to be a major characteristic of the entire world, when ideals and institutions alike seem to be trembling in their deepest foundations, though they rest on the traditions of many centuries, thoughtful people in all civilized countries are led to scrutinize the achievements of the human race with increasing misgivings. It is all very well for a modern mind to revel in the thrill of living in the most explosive and the most dangerously uncertain period in history. In more sober moments this same mind will, nevertheless, realize that the thrill is one of primitive savagery and not of enlightened civilization. Perhaps it will then turn to seek refuge in things inspirational that transcend the merely practical and material values of matters economic and political. Such are music, art, literature for a willing spirit that loves beauty; philosophy and theology for the roaming mind that delights in things unknown and mystical; natural science and mathematics for him who finds joy in consistent logic and symmetry of structure. But the mind that takes pride in calling itself modern will, no doubt, brush aside with ill-concealed impatience such achievements of the spirit, to point with genuine satisfaction to the material creations of science, and especially to its phenomenally successful applications in engineering and medicine. Here, indeed, is a wealth of visible accomplishment. Here are motor cars, airplanes, marvelous bridges and highways; floating palaces. Here are the telephone and the radio, the x-ray and the electric knife and innumerable other achievements of applied physical science and technical skill. Truly the scientific mind has made penetrating researches in many fields, all leading to an enrichment in human knowledge and to a multiplication of physical wealth. But has all this been a blessing? Is it because we have had too much science that the world is in a state of chronic depression? Have there been too many inventions and discoveries? Or is it that we have never learned to use the scientific scientifically? Are we, in fact, scientific in anything outside of the laboratories of natural science? How many of our modern minds that seek to keep abreast of this phenomenal multiplication of scientific knowledge have ever troubled seriously to discover what the so-called scientific method really is, how it works, and how it brings about the marvels of the "Age of Science"?

It is true that it is difficult for the layman, even if endowed with unusual intelligence, to obtain a clear picture of what even the most exact of the sciences, physics, deals with, and how it operates. On the surface there seems to be such an amazing contradiction between the magical success of the physical method, as measured by its applications, and the apparent instability of modern physical theory. In popular print physics seems to be overthrowing rather than building, yet the public continues to assume that the seemingly endless string of discoveries which the physicist turns over to the engineer and the medical man will work and work well. This diabolical trick of drawing success out of confusion is misleading, to say the least, and it may be in part responsible for the notion that the key to success in any field of endeavor lies in having a laboratory in which observations of one sort or another may be

made, in erecting imposing superstructures of conflicting and even contradicting theories and in adding the word science as a suffix. This method of beguiling the fairy, success, into a new domicile has not proved very satisfactory, and it has tended to popularize and even debase the very foundation of physical science, its methodology.

The truth is that physics is a very difficult subject, which must be understood from the ground up. The layman can, after a fashion, appreciate a symphony without knowing a thing about the technique of musical composition; but he can not well enjoy the theory of relativity without understanding much of physics, mathematics and critical philosophy. Physics works with complicated and intricate apparatus, with volumes of tabulated numbers under strange names, with still more volumes filled with innumerable mathematical symbols—all unintelligible to the interested but unequipped layman. And even when he discovers a familiar word, he is baffled to learn that it does not mean the same thing in the laboratory as on the street. So the scientific method continues to be an unsolved mystery to most laymen and philosophers, and to not a few scientists as well.

To make a difficult situation worse, some brilliant but mystical scientists have at times left the well-trodden paths of critical philosophy to venture into realms speculative and fanciful. From their fluent pens have come fascinating and romantic fairy stories to mystify the physicist and awe the layman. From their lips have come eloquent pronouncements about physics and religion, about space-time and eternity, that have been welcomed by the naive as the united voice of science and the supernatural, and hence of nature and nature's God in unison. But, as Einstein remarked, "You must distinguish between what is a literary fashion and what is a scientific pronouncement." Sir Arthur Eddington let his fancy play with a word, he expressed an opinion, it appeared in newspaper headlines, and ever since it is supposed by many that science has disproved the law of cause and effect, that it has established the freedom of the will. Notwithstanding the clear and convincing explanations by Planck, Einstein and Weyl, revealing the limited scientific meaning of the principle of indeterminacy, philosophers and preachers have continued to build castles of prejudice and desire upon an elementary misunderstanding.

In the meantime, the creative genius of pioneers like Planck, Einstein, Dirac, Heisenberg, Weyl and many others works persistently on, setting the compass for the hundreds of experiments, correlators, theorists and mathematicians who are blazing new trails or clearing and widening old ones. Mathematical-physical science is one of the truly great experiments of the human race; it is an experiment which has succeeded, not by building skyscrapers and constructing story after story upon them, but by burrowing down into the earth, digging tunnels and never hesitating to start anew, to fill in, to shovel or to blast, if that seemed desirable in finding the simplest way through that mysterious grain of the universe, the structure of nature.

II. Common Sense and Physical Science

The scientific method was not created by waving a wand. It has evolved by gradual stages from the so-called common-sense method. This, in turn, is founded upon the faculty of the human mind to receive impressions from the external world and to formulate judgments from these as to the structure of nature. It may be questioned at this early point, by those who have been convinced by the arguments of idealistic philosophers, whether there is such a thing as an external world, whether for any one individual, it is not made up

entirely of mind patterns, of ideas. However, if this contention be accepted, or even admitted for discussion, it becomes meaningless to talk about the scientific method at all. For it is precisely the object of physics to discover relations which obtain in an objective world outside of and independent of human perception and thought. Max Planck writes, "The fundamental principles and indispensable postulates of every genuinely productive science are not based upon pure logic, but on the metaphysical hypothesis that there exists an outer world which is entirely independent of ourselves." The existence of such a world is, therefore, presupposed in all that follows, together with the recognition that it is not directly knowable. Without these fundamental assumptions there would have been no science.

Before proceeding to examine the methodology of science, it is essential to examine briefly but critically the common-sense judgments of the ordinary man. These depend in the first instance upon crude perception by the senses, in particular by the eyes. No attempt will be made to discuss a theory of perception; it will be stated merely that the mind becomes aware of the outside world as a result of what are called sense-data. These are in the form of aggregates of color having a definite contour or of aggregates of sound having a definite sequence, etc. It is in searching for a cause and a comprehensive understanding of these aggregates that the mind invokes past experience as disclosed by memory. The association of successive sense impressions then leads to postulating the existence of definite objects as constituting the aggregate of repeated perception. Without enlarging upon the nature of such associations, it seems well to point out that they are not simple. Among other things they involve distinguishing between the object in question, its mirror image, a good painting or an hallucination.

The awareness of sense impressions, or memory thereof, is called a fundamental fact. Care must be exercised to distinguish between fundamental facts and inferences derived from them. Thus in the exclamation, "What a warm day!," the awareness of the individual of the sensation of hotness constitutes a fundamental fact which is not subject to further analysis or verification. On the other hand, the claim that the day is warm is an inference which may be subjected to further test, for example, with a thermometer. Fundamental facts of observation are the primary bases for ordinary or common-sense judgments. In forming such judgments, however, the individual is seldom guided alone by his awareness of certain sensations and his memory of others. Whether consciously or not, at least two other very important factors are involved. In the first place, the mind has acquired and stored in memory countless notions and ideas which are not derived directly from its own awareness, but from the accumulated judgments of other minds that have gone before it in the long evolution of the human race. In the second place, the imaginative powers of the mind are such that events which are physically meaningless or entirely impossible are readily conceived. And as a result of these, and generalizations upon them, the mind deals with innumerable subjects which are at best vaguely and extremely remotely related to direct sense-perceptions. Such are, for example, religion and mysticism which, frankly, depend not upon direct observation, but upon a mental heritage of faith and tradition.

It is clear, therefore, that the common-sense judgments of the ordinary man are composite ideas based in part upon direct observation of immediate or past experience, in part upon acquired and

unverified conceptions or upon purely imaginative associations and generalizations. The question arises, how reliable are these bases of judgment and, hence, how valuable are the judgments?

With reference to crude perception and the direct associations which depend upon it through the simple faculty of the memory, it is obvious that qualitative notions of very limited accuracy and questionable reproducibility are the best that may be expected. "The truth is," writes Whitehead, "that our sense-perceptions are extraordinarily vague and confused modes of experience." Perception depends upon relative conditions; it is limited by the shortcomings of the senses due to fatigue, nervous action or mental habits or by their innate insensibility. The eye, for example, is sensitive to only a very narrow band of electromagnetic waves and, in some individuals who are color blind, the range is still more restricted. If a drop of liquid air be placed on an individual's hand, the probability is that he will be ready to swear an oath that he has been burned by a hot liquid, simply because the sense organs are unable to distinguish between extremes of heat and cold. Optical illusions furnish a multiplicity of other examples to show how unreliable crude observations and inferences drawn from them are. Furthermore, the mind has no standard of comparison other than that furnished by memory, and this is usually vague and far from accurate, since it includes not only remembered facts of perception, but also, and in no very orderly way, accumulated judgments of other minds.

As a result of these miscellaneous accumulations in memory, the judgments of the mind are inevitably colored by personal habits of thought, by traditions of the times, by prejudices which have become parasites, by simple beliefs which are accepted on faith, by personal desires and ambitions. The human mind is not objective: It is far easier for an individual to see what he would like to see, to remember that with which he agrees or to think he understands that he hears repeated most often. Need it be said that traditions and prejudices of any kind are powerful warping influences in the forming of judgments? Thus the mind persistently seeks what it wants to find, or what it feels it ought to find. The Greeks, for example, argued that the planets must move in circles because the circle is the noblest geometrical figure. The modern mind frequently opposes the quantum theory or relativity because it feels, as a result of its limited experience, that nature should be continuous or absolute.

Unfortunately, personal prejudices about individual questions are not the only unwelcome visitors in memory's disorderly storehouse. From the beginning of science there has been a struggle between facts of observation and blind faith in an accepted authority. Religious beliefs or even unquestioning trust in the works of men like Aristotle and Newton have prevented not merely a reasonably objective association of ideas, but have definitely interfered with the correct perception of the fundamental facts of observation: Witness the distinguished professors of the University of Pisa who believed a not even correctly quoted Aristotle, rather than their own eyes, when Galileo demonstrated the laws of falling bodies. And if it is not blind faith, it is personal ambition or desire that corrupts the mind's judgments. Pope Urban VIII rejected Galileo's findings after having accepted and commended them in writing, when he was made to believe that Galileo had made fun of him. Personal vanity thus proved stronger than love of truth. The virulent nationalism of Hitler's Germany, Mussolini's Italy and Stalin's Russia represent similar situations on a large and dangerous scale in our modern times. As for America, one need but recall a recent article in *Harper's Maga-*

zine entitled, "If Industry Gave Science a Chance." The world over, wherever there is selfish ambition, the human mind believes in profit, not in truth.

Just as the mind will believe blindly and insidiously, so the imagination will construct and generalize without restraint. Carefully directed imagination and generalization are among the mind's most powerful means of discovery, but the ordinary constructs of the imagination, the fanciful extrapolations from observed facts, and the facile generalizations of the common-sense mind are among the most dangerous enemies of scientific exactitude. To use the imagination wisely presupposes a willingness, even a deep desire to discard or modify the most beautiful picture created by the mind at a moment's notice, if fact should so require.

Common sense has maintained, and millions have been ready to swear to the truth of the following statements, selected at random from the history of knowledge: (1) The earth is flat. (2) Heavy bodies fall faster than light ones. (3) A pint of alcohol and a pint of water give a quart when mixed. (4) There can be no light spot in the center of the shadow cast by an opaque sphere. (5) The velocity of light measured by an observer moving toward a source of light must be greater than that measured by a stationary observer by the amount of his own velocity relative to the light source. Each and every one of these common-sense conclusions has been proved wrong by subsequent experimental demonstration. It follows, therefore, that the common-sense basis for passing judgments is inadequate and unreliable. Seemingly obvious generalizations drawn from crude perception, modified by past experience as revealed by a memory of uncertain dependability, and as flavored by prejudice and tradition, are more often than not out of accord with the scheme of things, inconsistent with the structure of nature. To quote Millikan: "But after all, the evidence of our eyes is about the least reliable kind of evidence which we have. We are continually seeing things which do not exist, even though our habits are unimpeachable." Or, in the words of Whitehead: "The obvious common-sense notion has been entirely destroyed (by science) so far as concerns its function as the basis for all interpretation. One by one, every item has been dethroned."

The growth of science is the evolution of a means of overcoming or avoiding the limitations, the uncertainties and the ambiguities of common-sense judgments. Science has been and continues to be the development of a method for discovering the structure of nature and formulating it in a way that is simple and unfailingly true. In its quest for means by which to live in harmony with natural law, the human mind has advanced from common sense to the methodology of science.

III. The Methodology of Science

Convinced that the judgments of the unaided and untrained mind continually run counter to the true grain of things in the external world, one is led to ask modestly: What is the fundamental purpose of natural science and how does its methodology find footprints to follow in sands untouched by living feet? The man in the street never inquires beyond the first question, and its answer seems obvious to him. Is it not clear that the purpose of science must be the development of means by which man gains mastery over nature, so that he may profit from her hidden secrets and treasures? Bluntly stated, to the common man the purpose of science is a very material and practical one. Now, since the ordinary man deals entirely with things, it is only natural that his measuring stick should be that of practical value. Goethe writes: "Die Menge fragt bei einer jeden bedeutenden Erscheinung, was sie nuetze, und sie hat nicht unrecht; denn sie kann blos durch den Nutzen den Wert einer

Sache gewahr werden." But the measuring stick of physical science is not that of material things. To quote Poincaré: "Science cannot know things but only relations"; Goethe goes on to say: "Die wahren Weisen fragen, wie sich die Sache verhalte in sich selbst und zu anderen Dingen, unbekuemmert um den Nutzen, d. h. um die Anwendung auf das Bekannte und zum Leben notwendige, welche ganz andere Geister, scharfsinnige, lebenslustige, technisch geuebte und gewandte, schon finden werden." Finally, Whitehead writes: "The utmost abstractions are the true weapons with which to control our thought of concrete fact." Thus, the true aim of science should not be, and can not be, a practical one; science deals with relations unmindful of whether they have an immediate use or not. And the history of science reveals that the greatest scientific achievements have been the reward of those who have sought no practical value. To avoid misunderstanding, however, let it be noted that science in no way objects to having its discoveries put to practical use. But the very life of scientific research depends upon its not being engulfed in the emotional flux of human existence of which the patron saint is practical value and not scientific truth.

What, then, is the real aim of science? Broadly expressed, it is to discover unity in diversity. More precisely, it is to reduce the diversified quality observed in nature to coordinated and unified quantity. The pursuit of this aim involves two groups of problems. The first of these is the problem of analysis, namely, the measurement of nature's diversity, and the positivistic coordination of these measurements. The second is a problem of synthesis. It is the creation of a system of representation into which the coordinated measurements may be translated, and in which unity can be and is discovered. Before considering the solution of these two problems in turn, let it be emphasized, in the words of Planck, that "it is an indispensable postulate of all scientific research . . . , that natural phenomena invariably occur according to the rigid sequence of cause and effect."

Turning to the problem of analysis, Bertrand Russell writes, "The most essential characteristic of scientific technique is that it proceeds from experiment —not from tradition." And it is precisely by proceeding from experiment that the diversity of natural phenomena is measured. There are two kinds of experiment from which, in general, two kinds of facts are obtained. The first consists simply in observing carefully and repeatedly what happens in nature, and then having the observations verified by others. This type of experiment leads to qualitative facts. The second, and the more important type of experiment in physical science, leads to quantitative facts. These are the unique results of a very large number of highly accurate observations which are reproducible and observable by any trained observer. They are derived from refined experiments utilizing a high degree of technical skill and ingenuity. Their accuracy may be ascertained in terms of their reproducibility by applying the mathematical theory of errors.

As a consequence of this method of obtaining quantitative facts about nature in terms of operations and pointer readings, all physically real quantities, such as length, mass, force, etc., are defined in terms of the operations by which they are measured and in terms of arbitrary standards. It is an inevitable consequence of this operational mode of definition that the meanings of words such as force, length, etc., must be different from their meanings in the mouth of a layman. Physics defines those quantities which it measures directly in such a way that they have a precise physical significance as related to specific operations and to always available standards of comparison. The ambiguities of ordinary language are thus avoided.

To complete the analytical problem of measurement, physics correlates the measured quantities in the form of suitably tabulated and indexed groups. Such tabulations permit ready intercomparison of the results obtained by different observers and by different methods. In some cases it is then possible to draw positivistic conclusions which may be expressed in the form of empirical laws. Positivist philosophers often maintain that physics should stop at this point. But physics has not been convinced by their argument; it proceeds further; in fact, it jumps off into metaphysical spheres to find there its greatest triumphs.

In attempting to solve the problems of synthesis, physics has turned to mathematics. It is true that even in the solution of the problem of measurement mathematical language is used, but there it serves more the purpose of a convenient tool. In the solution of the problem of synthesis, on the other hand, mathematics is the very core of the mind's power to create. Without doubt mathematics is the greatest invention of the human mind; it is dynamic, amazingly powerful and unbelievably versatile. Those unfamiliar with higher mathematics are often inclined to believe that mathematics is nothing but a kind of glorified calculating machine or arithmetic on a grand scale. They are mistaken. In many ways mathematics is the greatest of humanities—it is a philosophy, a religion, a powerful tool, a true friend for leisure hours, if you will have it so. It need be neither cold nor dead nor matter of fact; and it is so many-sided that it finds its way into every field of knowledge. C. J. Keyser, of Columbia, writes: "The muse of mathematics is Logical Rigor, an austere goddess demanding though never quite securing absolute precision; demanding, though never quite securing absolute clearness; demanding, though never quite securing absolute cogency."

It is appropriate at this point to inquire what are the special characteristics of mathematics which make it the invaluable ally of theoretical physics in solving the problems of the structure of nature. First and foremost, mathematics deals with the understanding of relations. The properties of abstract relationships are expressed in terms of mathematical functions, and the mathematical theory of functions then provides the pattern for the study of relations and changes in relations. It will be recalled that physics is a search for relations existing in the structure of observable nature. Secondly, the mathematical theory of invariance deals with permanence, and hence serves as a framework for representing and studying forms, relations or properties which never change, but persist while all else is transformed. There must be permanence in the structure of nature, and physics must find and express it. Thirdly, and in the words of Weyl, "mathematics is the science of the infinite." Hence, it is peculiarly suited to handle such concepts as space and time, relativity and the absolute. In representing the infinite, mathematics introduces the concept of limit, and it is in terms of the mathematical limit that transcendental functions and transcendental concepts may be defined. For example, as C. J. Keyser points out, it is only with the aid of this concept of limit that a really satisfactory definition of an ideal in its most general sense may be given. Thus mathematical logic reaches out into the field of physics, but also into everyday life and thought. Specifically, mathematics might be explained to be a mental construct erected on arbitrary hypotheses in such a way that all steps leading from these to the final conclusions are logically related in terms of suitably designed symbols and operations.

The problem of theoretical physics is to translate the coordinated measurements and empirical relations obtained

by the experimental method into a pattern which may be mathematically expressed. Now, mathematical hypotheses are general and abstract statements, whereas experiment yields specific sets of values. The generalization of such sets of values is a problem of intuition and creation; its result is a physical hypothesis. This may be described as being an unproved assumption, arrived at as a result of scientific reasoning, which is believed to be partly or entirely true. It must be related to or be derived from experimental facts (or other hypotheses) in such a way that these may be deduced from it as logical consequences or results. The value of such an hypothesis is measured entirely in terms of the probability of its being true, though it is important and desirable that it be simple. Once such physical hypotheses have been conceived by a well-guided and critical imagination, they can be translated into mathematical symbols to become mathematical assumptions. Beginning with these, the stage is set for mathematics to operate independently. Before discussing how mathematics must now proceed, two matters deserve brief attention.

The first of these is the distinction between physical hypotheses and physical fictions, which it is important to bear in mind. A physical fiction is a statement which is known to be inconsistent with experimentally measured facts; a physical hypothesis, on the other hand, is believed to be in accord with these. Many physical fictions are both important and useful. Among these are mathematical abstractions such as points and lines, pictures, models, analogies and approximate solutions.

The second point deals with the possible inversion of procedure. Thus, although the primary mode of attack for the theoretical physicist is to create physical hypotheses from already available experimental data, he may imagine an hypothesis and predict from it the experimental facts required to verify it. If these facts are then found to support it, all well and good; if not, the hypothesis becomes a fiction. Actually in recent years theoretical and mathematical investigation has far outrun experimental work, since this latter is facing ever-increasing technical difficulties. It is significant to note that the mathematical method has become so powerful, and the theoretical investigators so skilful, that in most cases predictions are verified rather than disproved when the required experiments are finally performed with the usually extremely high degree of accuracy demanded. In any event, the order in which fact and theory are obtained is immaterial, so long as they finally support each other.

Let the main thread of the discussion now be resumed with a consideration of how the mathematical physicist proceeds after he has been provided with a physical hypothesis expressed in suitable mathematical language. His problem is to create a pattern to fit nature in the form of a unified mathematical representation which will satisfy all the existing hypotheses and all known facts. This is a problem in pure creation for which there is no method other than that suggested by individual intuition and genius. Before a solution of any kind is possible, however, a question of fundamental importance must be decided. The fact is that it is in general possible to represent a given set of hypotheses by a great many conceivable mathematical forms. The question is, what test is to decide which of the innumerable possible representations possesses a maximum of unity, since unity is the desired quality? The answer to this question is of primary significance; it is actually one of the basic assumptions of the entire methodology of science. It depends upon a definition, pure and simple, of what physical reality is to mean. Physical reality, and this is not to be confused with the numerous definitions of metaphysical reality provided by the several schools of phi-

losophy, is defined to be the simplest possible representation. D'Abro expresses it in the sentence, "What we call reality reduces to the simplest coordination of the facts of observation." It is interesting to note that this definition is in accord with the Greek ideal of esthetic value, though the Greeks did not, of course, require experimental verification. The justification for this definition of reality in physical science is twofold. In the first place, the definition is convenient and it is suited to the operation of the mind; in the second place, it has led to countless results consistent with the structure of nature. Evidently, then, there must exist a correspondence of some kind between simplicity, as recognized by the human mind, and what Leibniz called "preestablished harmony" in the external world. That is all that physics knows and need know to justify its method.

The solution of the entire problem of discovering unity in diversity has thus been envisaged in so far as the method pursued is concerned. Beginning with the quantitative facts of experiment, the physicist proceeds to create general physical hypotheses, to translate these into mathematical language and then to construct the simplest possible mathematical representation consistent with all available evidence. In the words of Einstein, "the supreme task of the physicist is the discovery of the most general elementary laws from which the world-picture can be deduced logically." This is the methodology of science.

IV. New Theories and Old Truths: the Evolution of Knowledge

As a consequence of the methodology just outlined, one may conclude that scientific knowledge has its inception in the accurate investigation of a great many facts, including those disclosed by carefully arranged and controlled experiments. Knowledge itself consists of unified representations of known facts from which it is possible to derive by logical steps all phenomena quantitatively and with precision.

But knowledge is never stationary so long as increasingly skilful minds, with ever more powerful experimental and mathematical tools, are finding their way deeper and further into the secrets of nature's structure. The growth of knowledge proceeds (1) from an increase in the number or the accuracy of available facts; (2) from "the creation of new mathematical constructs representing mechanisms or systems which account for facts already known and for facts discovered as a result of the new formulation."

Every new formulation, however, must win its case before the supreme and unyielding judge of all science, experiment. If it fails it becomes fiction, but may still continue to serve a useful purpose in a limited way. Such is the case with the Bohr theory of the atom and with Newton's law of universal gravitation. Any new and more general mathematical representation must include in the new form everything in the old which is verified by experiment or crude observation. Thus, the general theory of relativity must and does contain the Newtonian law of universal gravitation as a special and limiting case. Nothing which verifies Newton's law can or does disprove Einstein's; but new evidence which can not be explained in terms of Newton's law is explained and coordinated by Einstein's. Since, moreover, Einstein's law is at the same time the simplest and the most inclusive formulation which any mind has thus far conceived, and which does satisfy all available experimental evidence, it represents physical reality. It is to be noted that it is quite easy for mathematicians to prove that Einstein's equations are not the only ones consistent with the available evidence. But all alternative solutions so far suggested fall far short of Einstein's in unity, in simplicity and in mathematical elegance.

Physical reality may change from day to day; physical fact does not, except in so far as it is determined more accurately. What has been called revolution in physics is but the pulse of a gradual and persistent evolution. The methodology undergoes no radical or violent changes; it continues to be, in the words of D'Abro, "the formulation of a mental construct capable of coordinating in a simple and rational manner the sum total of our sense impressions." Experimental facts become ever more accurately known; mathematical representations become ever more general, more comprehensive, more unified. But facts remain facts, and what was once true continues true, at least during a timespan comparable with that of human history, for such is the structure of nature. New mathematical forms and new metaphysical speculations and mind pictures in no way alter the known facts about the scheme of things; they merely rearrange an understanding of these. Thus, the ancients were satisfied to let Apollo pull the sun across the heavens each day, to let Jupiter thunder his personal wrath and to let Atlas bear the world upon his shoulders while his feet rested in the "nether regions." Some moderns are still content to let a mysterious and hidden force called gravitation draw all bodies together. Meanwhile it is the aim of science to eliminate all gods, giants and hidden forces from the mind's representation of nature, and to substitute for these unified mathematical forms which coordinate symmetrically and systematically all known facts.

It would be unfortunate and incorrect to suppose that the scientific method is all-powerful and unlimited. Such is not the case. The methodology is definitely restricted by two significant factors. They are the genius of the human mind to create and comprehend, and the structure of nature itself. With regard to the first of these, the limit to the unity and generality of mathematical representation lies in the limit of the human mind to recognize unity, to encompass generality and to create mathematics. And the entire theoretical superstructure is limited by that most fundamental requirement—accurate experimental evidence. If and when the human mind can not devise means and methods for providing quantitative facts, then and there the methodology of science must fail to yield results consistent with the structure of nature. Among the limitations of the human mind is its inability to deal with several variables simultaneously. Many people think only in terms of one or two dimensions, although most are not incapable of comprehending three. When it becomes a question of a four-dimensional manifold, practically every one is completely baffled and helps himself by saying that common sense does not acknowledge the existence of such a monstrosity. But the limited value of such assertions has been demonstrated. Mathematics readily sets up problems in any number of dimensions or variables, such as some in quantum mechanics which require manifolds of several hundred dimensions. But the actual solution of problems involving many dimensions has not been accomplished in any general way.

Turning now to the limitations imposed upon science by the structure of nature, it is clear that every measurement reacts in at least a minute amount on the thing measured, and hence disturbs it. This is the core of the experimentally always verified Heisenberg principle of indeterminacy. It simply means that there must always remain a margin of doubt which no refinement in technique can ever eliminate. This margin of doubt or indeterminacy is of the order of magnitude of the smallest possible contact which can be made with the particle or quantity to be measured. Clearly such a contact involves the smallest package of energy which exists. Since this is of a definite, though ex-

tremely minute size, there is no way of reducing this smallest contact below a certain minimum. A single quantum of energy is so small that it plays no part whatsoever in determining the accuracy of macroscopic measurements dealing with large bodies and large quantities of energy. In microscopic measurements, on the other hand, such as the measurement of the position or the velocity of an electron, a single energy quantum is relatively so large that the margin of doubt in the measurement becomes extremely great. It is clear that the structure of nature thus definitely limits the experimental physicist in his microscopic measurements. The conclusion that, because nature does not provide infinitely divisible packages of energy, it is chaotic and not governed by cause and effect, is certainly not required by any scientific evidence. In fact, it is completely beyond the realm of scientific inquiry to draw such a conclusion. To extrapolate still further, and to affirm that science proves anything about the freedom of the human will, is absurd. The awareness of an individual of whether his will feels free or determined is entirely outside the field of application of scientific methodology at the present time.

The fact that physical science has advanced by leaps and bounds is sufficient evidence to suggest that its limitations have not as yet proved a serious handicap. The mind grows as it creates, and what may be an insurmountable obstacle in its path at a given stage of development may be overcome by a succeeding generation of scientists. On the other hand, the recognition and the discovery by physics of such fundamental limitations as that stated by the principle of indeterminacy are achievements of the first rank. It is real knowledge to know that there can be no perpetual motion and that there is a definite limit to experimental measurement of microscopic phenomena. Such discoveries are signposts that reveal that the structure of nature is not uniformly putty-like. It is between such guiding beacons that science must continue to feel its way into the fathomless unknown. Shortly before his death Newton wrote: "I do not know what I may appear to the world, but to myself I seem to have been only a boy playing by the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay undiscovered before me."

In a brief conclusion, it may be said that the methodology of science is the only consistently successful method the human mind has discovered to learn something about the true structure of nature. And it is only with the aid of such knowledge that a groping mind can adjust itself to harmony with natural laws in the most general sense. The modern mind might well strive to realize, as Newton's did, that its judgments are like answers to the question, How many stars are in the sky? and that its enlightenment is like that of a man exploring the universe in a starless night with a single match. To be sure, science itself is but a new-born child in the great march of the centuries, and its future is unpredictable. But perhaps the time will yet come when a maturer science will lead a saner world to harmony with the scheme of things in all rational fields of human endeavor and thought. And if it does, then there will have echoed through countless centuries the words of Lord Kelvin: "When you can measure what you are speaking about, and can express it in numbers, you know something about it, and when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely in your thought advanced to the stage of science."

SUNLIGHT AND HEALTH

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THE number of abnormal conditions primarily and specifically benefited by sunlight, natural or artificial, is small in comparison with the number for which such claims are made. Sunlight constitutes one of the benefits of an outdoor life; it is one of the elements of climate that make for physical and mental well-being; in extrapulmonary tuberculosis, when judiciously used, it aids and promotes healing; in rickets, certain wave-lengths are specific; but these facts do not justify the extravagant claims made for it as a vitally necessary curative and preventive agency. Certain diseases and disabilities are partly due to deficient radiation, and doubtless the health of the community may be improved by providing more artificial radiation where sunlight does not reach the small minimum required for health; but sunlight is only one of the many environmental factors that influence health. Climate in its relationship to health is not merely a question of sunlight, but of fresh air, wind, temperature, humidity, altitude above sea level, etc., as well. "Heliotherapy" includes all these, as well as diet and occupation. Sunlight is of paramount importance to plants, but of secondary importance to animals. Because a certain portion of the solar spectrum is specific in preventing and curing rickets, and exposure to sunlight promotes the healing of certain manifestations of tuberculosis, does not imply that every one is suffering from a lack of sunlight. Sunlight plays a subordinate part in the regulation of the physical and chemical processes that make up the life of normal man, who can get along with little or practically none of it, provided his diet be adequate and that he take care of himself in the way of getting plenty of fresh air, sleep and exercise.

All sunlight is not *light*, which is that agent, force or action in nature by the operation of which on the organs of sight objects are rendered visible or luminous. Light is visible radiant energy. When sunlight is passed through a prism it is broken up into its constituent parts, it is dispersed, and if the dispersed rays are focussed on a screen they form a spectrum with the red rays at one end and the violet at the other (see Fig. 1). These rays have definite wave-length, extending approximately from 400 millimicrons at the violet end to 800 millimicrons at the red. There is an octave, so to say, of visible spectrum. To either side of these visible wave-lengths of radiant energy there is invisible radiant energy. On the violet side there is the "ultra-violet," extending in sunlight to about 300 millimicrons, shorter wave-lengths being detectable only under conditions of exceptional atmospheric purity. At the red end there is the "infra-red," extending in sunlight for all practical purposes to 3 microns (3,000 millimicrons), only 1 per cent. of the total solar spectrum being found at wave-lengths longer than this. The total amount of ultra-violet radiation shorter than 310 millimicrons is extremely small, usually only from 0.01 to 0.1 of 1 per cent. and not more than 0.2 of 1 per cent. of the total on the clearest days at noon in summer at sea level at mid-latitude.

Although these invisible ultra-violet and infra-red rays or wave-lengths are certainly not light, being invisible or non-luminous, they are, more often than

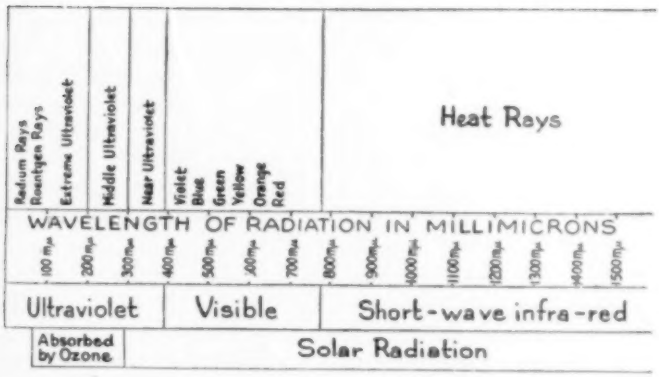


FIG. 1. THE CONSTITUENT PARTS OF THE SPECTRUM OF RADIANT ENERGY.[1]

not, included in the implication of that word. In this sense light has come to include not only visible energy (light, *in sensu strictu*) but also ultra-violet and infra-red energy. Usage, even when fundamentally incorrect, is difficult, if not impossible, to combat.

Sunlight is our natural source of "light" for treatment. In many places, however, its intensity varies too much or is too weak for too great a proportion of the time to permit of its being a practical source. As artificial sources the mercury vapor arc in quartz, the flaming carbon arc and "heat" radiators are the only ones of practical importance. The penetrating long-waved luminous and short-waved infra-red rays emitted by tungsten lamps (200–500 watt) and by parlor or bathroom electric heaters are of value in conditions requiring deep action, in the relief of deep-seated pain, as in sprains, fractures, pulled tendons, bruised muscle, etc. The energy emitted by the quartz mercury arc and the carbon arc extends farther into the ultra-violet and infra-red regions than does the energy of sunlight. The flaming carbon arc extends from 218 millimicrons to about 6 microns, while the energy emitted by a quartz mercury lamp begins at 185 millimicrons and ends in the long infra-red.

At the surface of the earth, with the sun moderately high and a total intensity between 1 and 1.5 gm. cal. per sq. cm. per min. (70,000 and 105,000 microwatts per sq. cm.), the percentage of the energy that is ultra-violet is between 1 and 5, luminous between 41 and 45 and infra-red between 52 and 60. When the sun is lower and the total intensity less, the ultra-violet is relatively decreased and the infra-red increased. At high altitudes above sea level the total energy is increased and with this the percentage of ultra-violet, while that of the infra-red is diminished.

The radiation from the flaming carbon arc is the closest approximation to natural sunshine. In one of our lamps with 25 amperes flowing through the arc, burning sunshine carbons, the total energy emitted is 0.325 gm. cal. per sq. cm. per min. incident at a meter, or 1 gm. cal. at 57 cms., and 1.5 gm. cal. at 46.6 cms., with a distribution of 6 per cent. ultra-violet, 50 per cent. luminous and 44 per cent. infra-red. With a Corex D screen, which eliminates by absorption the ultra-violet and infra-red rays not found in sunlight, the total energy emitted is 0.287 gm. cal. incident at a meter, or 1 gm. cal.

[1] This diagram is adapted from one appearing on page 12 of "Light and Health," by M. Luckiesh and A. J. Pacini, published by the Williams and Wilkins Company.

at 53 cms., and 1.5 gm. cal. at 43.4 cms., and its distribution is 5 per cent. ultra-violet, 63 per cent. luminous and 32 per cent. infra-red.

A larger percentage of ultra-violet can be obtained by using other carbons, *e.g.*, the "Therapeutic C" carbon. When these are burned, no glass screen being used, the total energy emitted has the same value as the "sunshine" carbons, but the distribution is 9 per cent. ultra-violet, 24 per cent. luminous and 67 per cent. infra-red. Mercury lamps have quite different distribution spectra from these values, for instance, a new mercury lamp (4 to 5 amps., 70 to 80 volts), emits 28 per cent. in the ultra-violet, 20 per cent. in the luminous and 52 per cent. in the infra-red; and an old mercury lamp in our laboratory has a distribution as follows: 13 per cent. ultra-violet, 7 per cent. luminous and 80 per cent. infra-red. The total energy emitted is much lower than in the carbon arc and in sunlight (about 0.06 gm. cal. per sq. cm. per min. incident at a meter) in agreement with the lower power input.

The almost immediate reddening of the skin on exposure to sunlight or to a flaming carbon arc is due to radiant heat (infra-red and long luminous) rays. It is followed in a few hours by the erythema or "burn" due to the action of the ultra-violet rays. An artificial source must emit a certain minimum amount of ultra-violet in order to insure effective therapeutic action when such wave-lengths are indicated. The amount of ultra-violet radiation that can be applied to the body without producing a burn depends on the tolerance of the skin, which can be measured by the erythema or burn produced, specifically a mild or "minimum perceptible erythema," one that disappears in the course of twenty-four hours. This reaction is produced by wave-lengths shorter than 315 millimicrons. The midday, mid-latitude, sea-level ultra-violet shorter than and including 313 millimicrons in summer sunshine with an intensity of from 80 to 90 microwatts per sq. cm. produces a minimum perceptible erythema in from 20 to 45 minutes, depending on the person. In winter when the intensity is only about 20 microwatts (on the clearest days at noon) the time is lengthened to from 3 to 5 hours. Forenoon and afternoon summer sunlight has an average intensity of 30 microwatts per sq. cm. Judged by the erythemal response the intensity of wave-lengths less than and including 313 millimicrons emitted by an artificial source should not be less than 20 microwatts (Coblentz).

There is no close relationship between the spectral erythemic response and the general therapeutic or curative action of radiant energy, but the erythemal reaction is taken as a criterion for judging the effectiveness of a lamp for three reasons: (a) It is practically the only physiologic reaction that is established with a relatively high degree of accuracy; (b) it is a simple and practical means of preventing severe burns, and (c) it is an efficient safeguard against the sale of lamps that are deficient in ultra-violet radiation. The effective ultra-violet emitted by the present-day "professional models" of the various kinds of therapeutic lamps greatly exceeds the specific minimum value of 20 microwatts.

The Influence of Sunlight on the Skin

The skin is not simply a protection but an organ with nervous, nutritional, circulatory and excretory functions. Its exposure to radiant energy improves its blood supply with consequent improved nutrition and removal of waste. It is the organ most immediately and intimately acted upon by "climate." A toneless and inelastic skin, white with yellowish tinge tending to grayish and quite dry,

LAYER	λ mm	200	250	280	300	400	550	750	1000	(1400)	μμ
		100	100	100	100	100	100	100	100	100	APPLIED
CORNEUM	.03	(100)	(81)	(85)	(66)	(20)	(13)	(22)	(29)	(56)	ABSORBED AND REFLECTED
		0	19	15	34	80	87	78	71	44	TRANSMITTED
+MALPIGHII	.05	(0)	(8)	(6)	(18)	(23)	(10)	(13)	(6)	(16)	ABSORBED
		0	11	9	16	57	77	65	65	28	TRANSMITTED
+CORIUM	.20	(0)	(11)	(9)	(16)	(56)	(72)	(44)	(48)	(20)	ABSORBED
		0	0	0	0	1	5	21	17	8	TRANSMITTED
+SUBCUTAN.	.25	(0)	(0)	(0)	(0)	(1)	(5)	(20)	(17)	(8)	ABSORBED
		0	0	0	0	0	0	1	0	0	TRANSMITTED

	EXTREME U-VIOL.	FAR ULTRA VIOLET	NEAR U-VIOL.	VISIBLE VIOL. GREEN RED	NEAR INFRA RED	FAR INF. RED
GENERAL REMARKS	All absorbed by corneum. No radiation reaching germinativum.	Greatest absorption in stratum corneum. Some radiation reaches corium (papillare). No radiation reaches subcutaneous layers.	Relatively large absorption in stratum Malpighii.	Minimum absorption in stratum corneum. Most radiation absorbed in corium. Pronounced radiation reaching subcutaneous layers.	Strongly increasing absorption in upper layers, decreasing in lower layers.	Practically no penetration.

FIG. 2. ENERGY DISTRIBUTION IN THE LAYERS OF THE SKIN. THE NUMBER 100 DESIGNATES THE APPLIED INTENSITY. THE ENCIRCLED NUMBERS REPRESENT PERCENTAGES ABSORBED IN EACH LAYER. THE NUMBERS IN THE NARROW ZONES BETWEEN LAYERS REPRESENT THE PERCENTAGES OF THE ORIGINAL INTENSITIES TRANSMITTED THROUGH THE LAYER ABOVE. (BACHEM AND REED.)

may, after 3 to 4 weeks' stay at the seashore, appear entirely changed, and not only that portion which is exposed to the sun and therefore tanned, but the unpigmented, covered skin, which becomes pink, soft, smooth and elastic. The color of the skin, to a certain extent, serves as an index of the state of well-being and has been interpreted as evidence of health or disease.

The skin reflects and transmits different parts of the spectrum quite differently, and different parts of the body behave differently. Pigment, hair and blood are important elements in determining the relative amount of the energy absorbed. Fig. 2 shows the relative penetration of important wave-lengths between 200 and 1,400 millimicrons, as determined by Bachem and Reed. The blood which flows through the skin is of great importance. The more the capillaries are filled, so much the more the shorter rays will be taken up by the blood and given up to the organism as a whole, and so much the more the long-waved energy will pass through the network of blood vessels and penetrate to the deeper layers of the body.

Erythema and Pigmentation: As above mentioned the almost immediate reddening of the skin after irradiation with energy containing ultra-violet, luminous and infra-red rays is due to radiant heat (short infra-red and long luminous rays). This heat reddening frequently has a mottled appearance and is not restricted to the irradiated parts of the skin and disappears soon after the irradiation is stopped. It is followed in a few hours by a "burn" due to the action of the ultra-violet rays. The usually diffuse and homogeneous redness of this "burn" is confined strictly to the irradiated part and, according to the intensity of the radiation, may be combined with

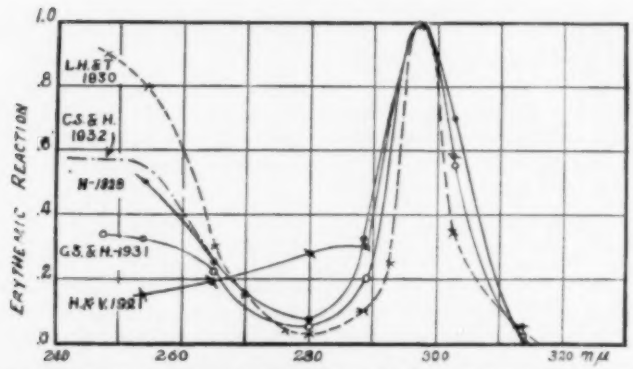


FIG. 3. RELATIVE SPECTRAL ERYTHEMIC REACTION OF THE HUMAN SKIN TO EQUAL AMOUNTS OF RADIANT ENERGY AT VARIOUS WAVE-LENGTHS AS DETERMINED BY SEVERAL INVESTIGATORS. (COBLENTZ, STAIR AND HOGUE.)

blistering and hemorrhage. The inflammation lasts for some time, to be followed by peeling and pigmentation. "Sunburn" and the inflammation or "burn" caused by carbon and other arcs is one and the same thing. As Fig. 3 shows, the wave-length range of the rays producing sunburn begins at about 315 millimicrons and extends to an undetermined wave-length shorter than 240. The erythemic response curve rises steeply to a maximum at 297, descends to a minimum at 280 and then rises to a less intense maximum in the region of 250.

Ellinger has studied the ultra-violet erythemal reaction of many hundreds of subjects and reports great variability in the sensitivity of different individuals. Blondes are much more sensitive (40–170 per cent.) than brunettes, and women less sensitive (20 per cent.) than men. All persons under 20 and over 50 have a lowered sensitivity. There is a maximum sensitivity in March and April and again in October and November (see Fig. 4). Persons with an unstable nervous system, an overactive thyroid gland or with high blood pressure or active tuberculosis also show a quite high sensitivity.

The observations of Sir Thomas Lewis show that in all types of skin injury the vascular response is brought about by the action of a chemical substance liberated in the tissue spaces as a result of the injury. This hypothetical diffusible substance is a histamine-like substance or even histamine itself and is called H-substance. According to Ellinger, the thyroid gland is primarily responsible for the increased sensitivity and there is a relation between the number of open, that is functioning, skin capillaries per surface area and the light sensitivity. If the activity of the thyroid gland is increased the metabolic rate is increased and the body temperature shows a tendency to rise. In order to prevent this, that is to say, in the interests of the regulation of the body temperature, there is an increase in the number of open, functioning capillaries in the skin, which increases, *pari passu*, the sensitivity to the erythema-producing ultra-violet rays.

Function of Pigment: The essential function of the skin pigment, melanin, has for long been thought to be the protection it affords the organism against excessive irradiation. Every one has observed how the skin of persons accustomed to an outdoor life, and thus tanned or pigmented to a greater or less degree,

does not react on exposure to strong sunlight, which acts painfully on the unaccustomed, unpigmented skin of others.

Ectodermal pigment is found in the epidermis, almost exclusively in the basal cells, chiefly in characteristic cap form over the distal pole of the nucleus, but also in branched cells (Fig. 5, p. 323). The other living cells of the epidermis and the horny layers in the white race contain pigment in considerable amount only when pigmentation is extreme. In Negroes not only is pigment more abundant in the basal layer, but there is also much pigment in the outer, including even the horny, layers. The mesodermal pigment is in the corium, or cutis vera, and does not interest us here.

Considerable evidence has been recently brought against this view, first clearly expressed by Finsen and quite universally held since his day, that a pigmented skin was protected against excessive damage by ultra-violet rays shorter than 315 millimicrons. The "modern point of view" concerning the protective function of the skin against ultra-violet is as follows. The shorter-waved rays are absorbed superficially in the horny layer (about 30 millimicrons thick), and thus never reach the living cells of the epidermis. ***The horny layer is the screen for the epidermis against the shorter ultra-violet rays.*** The longer-waved ultra-violet which penetrates as far as the true skin (thus at least 50 millimicrons) may act on the blood in the capillary vessels of the true skin. The basal layer pigment, which increases after irradiation with ultra-violet shorter than 315 millimicrons, regulates the amount of this longer-waved energy, which reaches and penetrates the basal cells and thus protects the underlying true skin from receiving too much energy. ***Pigment is the screen for the true skin against the longer ultra-violet rays.***

Quite a number of authors believe that this pigment absorbs the luminous and short infra-red rays so that the heat effect is localized at the surface, from which it may thus be more readily lost, so protecting the body as a whole from overheating. The advantage enjoyed by dark-skinned persons over fairer ones in a hot climate in the way of greater tolerance to the rays of the sun is thus plausibly assumed to be demonstrated. The Negro's skin heats sooner and to a greater extent than does that of the white man; he therefore sweats more copiously and, what is also of importance, the sweat evaporates more quickly, owing to the higher temperature of the skin. All this, however, while plausible, is almost all assumption, and what accurate work has been done to demonstrate it has failed. Briefly, we may say that pigment absorbs, to varying degrees, all the wave-lengths of sunlight. Its protective function is but slight in white-skinned persons, more important in dark-skinned races, particularly for the ultra-violet rays. The increased absorption of penetrating heat rays does not appear to give the Negro any advantage over the white man in regulating his body temperature.

Therapeutic Value of Pigment: There

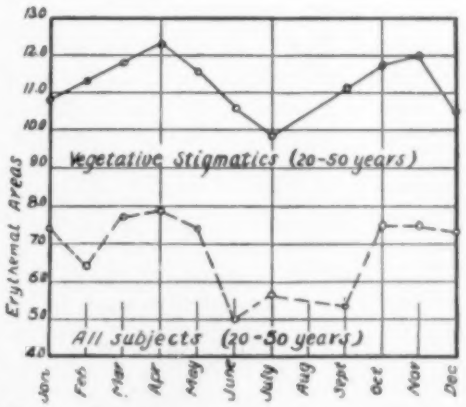


FIG. 4. SEASONAL VARIATION IN ERYTHEMIC REACTION IN NORMALS AND IN THOSE WITH AN UNSTABLE NERVOUS SYSTEM. (ELLINGER.)

is no unanimity of opinion. Many regard pigment, owing to its absorption, as unfavorable for the action of "light" and therefore attempt to prevent its formation. Others ascribe to it a very important value and believe that the degree of pigmentation is a favorable diagnostic sign, brunettes thus responding better to insolation than blondes.

A logical statement, in view of the evidence at hand, is that pigment formation and healing, or benefit from the energy, seem to represent independent, coordinate phenomena proceeding simultaneously in the same direction. Since the horny layer is a more important protector against over-irradiation by shorter ultra-violet rays than is the skin pigment, there is left but one outstanding significant connection between radiation and pigment, namely, as an indicator of the action of the radiant energy, its intensity being, to a certain extent, proportional to the amount of action. But it is also very dependent upon individual factors such as race, constitution and body function. Pigment formation is an indicator of the wished-for action and can be used as a measuring rod for treatment and, since pigment formation, horny layer thickening and possible chemical alterations of the skin cell proteins run practically parallel, it is also a measure of adaptation or of lowered sensitivity.

The Effect of Radiant Energy on Wounds and on Some Skin Diseases: Natural sunlight will hasten the healing of sluggish, indolent wounds, as was demonstrated so clearly in 1902 by Oscar Bernhard at Samaden, Switzerland. The effect, however, is certainly not specific to the short ultra-violet rays but brought about by wave-lengths that penetrate through the epidermis and part of the dermis, producing their action indirectly through the circulation. The surface action of ultra-violet wave-lengths shorter than 315 millimicrons in large quantity is detrimental to the healing of wounds, unfavorably influencing the processes of repair. The beneficial influence is due to longer ultra-violet, luminous and short infra-red rays.

Until Finsen, by means of strong carbon arc radiation, cured so many cases of tuberculosis of the skin (about 60 per cent. of those he treated) the disease had been regarded as almost incurable. Reyn has found that local treatment combined with general exposure is beneficial in approximately 90 per cent. of cases. The result of the treatment depends, as in the treatment of wounds, upon the depth of the action of the effective rays, and, in selecting the source, the one with the maximum penetration of these rays must be chosen, namely, the flaming carbon arc lamp.

Tuberculosis of the skin (*lupus vulgaris*) seems to be the only skin disease on which ultra-violet rays act specifically as a result of direct action or indirectly through general body irradiation. Of skin diseases for which claims are made for the beneficial action of sunlight and artificial radiation the following may be mentioned: dry and weeping eczema, pruritus, local and generalized urticaria, psoriasis, *acne vulgaris*, varicose ulcers with associated dermatitis, vascular nevi, *alopecia areata* and the loss of hair following severe infections, but the improvement that may follow is not a specific effect. In some cutaneous disorders (eczema, urticaria, psoriasis, *lupus erythematosus, herpes simplex, xeroderma pigmentosum*, farmer's skin, prematurely senile skin) exposure to such rays may cause a flare-up or provoke an attack.

Influence of Sunlight on the Blood and Circulation

The influence of sunlight on the blood may be passed over briefly, since, while radiant energy, including longer ultra-

violet, luminous and infra-red rays, such as natural sunlight and its close approximation—the energy emitted by "Sunshine" carbons—may have some effect on secondary anemia, this is limited, not specific, and merely adjuvant to established dietetic and drug treatment. Irradiation of this sort may also be used in cases of diminished platelet count, as in some instances of *purpura hemorrhagica* (idiopathic). We have seen one very significant case in our laboratory in which a 5-year-old boy, refractory to all other treatment and for whom removal of the spleen had been advised, was given 7 graded carbon arc irradiations over a period of two weeks, with an increase in the platelet count from 45,000 to 400,000, at which high level it remained for 3 months when the patient was dismissed. The boy has been now symptom-free for four years.

Ultra-violet rays alone do not lower blood pressure, but carbon arc radiation ("Sunshine" or "Therapeutic C" carbons) does—that is to say, of a certain percentage (from 60 to 70) of persons with abnormally high blood pressure. I have shown in both ambulatory and hospitalized patients with essential hypertension that both systolic and diastolic pressure may be materially reduced (from 10 to 15 per cent.) by general carbon arc irradiation. The "cure" is temporary, and the treatments have to be repeated, being given every ten days or two weeks in those whose pressures have been lowered by earlier more often repeated large doses (usually every fourth or fifth day). The individual doses must be large enough to set up an inflammatory reaction, accompanied by marked vasodilatation, not too frequently repeated, so as to avoid adaptation.

The amount of blood ejected by the heart per minute (the cardiac output) shows a significant tendency to increase when the blood pressure is lowered by carbon arc irradiation. This may be a compensatory reaction secondary to the dilation of the blood vessels and the drop in blood pressure.

The Influence of Sunlight on Mineral Metabolism

Rickets: Ultra-violet rays shorter than in rectifying the partial lack of the 313 millimicrons are of great importance dietetic components necessary for building bone. The process of irradiating a baby with such ultra-violet wave-lengths consists in giving rise to vitamin D from the provitamin in the skin. The irradiation influences the formation of vitamin D and the storage of calcium and phosphorus and the equilibrium of these elements in the blood stream of mature animals in a way similar to the effects upon growing animals, and the antirachitic factor represents specifically the organic agent which promotes normal calcium anabolism. It may prevent and cure rickets, it may promote growth, or it may simply prevent excessive loss of lime from the body. The specific capacity in which it functions depends upon the condition of the animal, both with respect to age and nutrition, and upon the composition of the diet. Radiant energy simply revives, or aids, a depressed function. The antirachitic vitamin D is prepotent in preventing rickets, and is capable of doing so in the entire absence of sunlight. Ultra-violet radiation may rectify partial but not absolute lack of the dietetic components necessary for bone and teeth calcification. Ultra-violet rays of wave-length 313 millimicrons and shorter and vitamin D cause the organism to operate more economically, they make metabolism more efficient, they permit the organism to have full use of normal processes which are not effective, but they do not bring new processes into operation. Ultra-violet plus luminous and infra-red radiation does

not favorably influence the union of fractures.

Teeth: Diet influences the formation of teeth by virtue of vitamin D, which increases and controls the actual calcifying process and by containing sufficient calcium and phosphorus. The vitamin seems necessary not only for the original development of the tooth but for its protection later in life. In dental caries, rickets seems to be merely one of several etiologic factors. Dental caries is not the result of low calcium or low phosphorus content of the blood. A comparative study of enamel, dentin and bone in newborn and very young infants shows quite clearly that the formation of enamel and that of dentin in the unerupted teeth do not parallel each other but that those of bone and dentin do. Enamel is an epithelial tissue arising in the ectodermal layer of the embryo, while bone and dentin are connective tissues originating in the mesoderm. This may be why the teeth of children with marked stigmas of rickets are often well formed and free from decay, and why tooth decay may be rampant in rapidly growing, breast-fed infants in the tropics, with no evidence of rickets.

Milk in Rickets: As human milk or that of some animal forms the almost universal diet of infancy, it has been surprising to learn that rickets can occur so frequently. One expects milk above all foods to embody the essentials for good health and development during infancy. But milk is poor in the antirachitic factor, vitamin D, of which even the highly prized human milk contains only a small amount. Consequently any high protective value of human milk in infantile rickets can not be ascribed to its content of the antirachitic factor.

Since the introduction of irradiated ergosterol and irradiated foods for the prevention and treatment of rickets, several methods have been satisfactorily employed to impart anti-rachitic properties to milk, such as (1) the irradiation of milk in powdered, evaporated and liquid form; (2) the irradiation of the mother or of the wetnurse; (3) feeding to the cow irradiated yeast, and to the woman cod liver oil or irradiated yeast; (4) adding irradiated ergosterol (yeast) to the milk; (5) adding to the milk a vitamin D concentrate prepared from cod liver oil.

Infantile Tetany: Infantile tetany is a symptom complex which occurs in rickets when the salt equilibrium in the blood happens to be of a kind which sets the nervous system in a state of hyperexcitability, namely, low calcium, and it is with the low calcium form of rickets that manifest tetany is associated. Any agent capable of raising the calcium concentration to a level within 20 per cent. of the normal will cure the active manifestations of tetany. The treatment of choice is a combination of some salt of calcium and irradiated ergosterol (viosterol).

Activation

The independent and almost simultaneous demonstration in 1924 by Hess and by Steenbock and Black that certain substances, inert in so far as calcifying and growth-promoting power are concerned, may have these capabilities bestowed upon them by irradiation has proven to be of far-reaching importance. The facts that when an animal is irradiated its skin, liver and muscle become antirachitically active, and that eggs and milk have increased or newly endowed calcifying and growth-promoting powers bestowed upon them; and that foodstuffs deficient in the antirachitic vitamin may have it supplied to them by judicious irradiation, have proven not only of interest and of therapeutic value, but have done much toward clarifying our conception as to the mode of action of sunlight and of vitamin D in the prevention and cure of

rickets. Ultra-violet radiation forms vitamin D either in the cells of the living creature or in its foodstuffs. The action of a foodstuff artificially rendered antirachitic by irradiation is identical with the action of a naturally occurring foodstuff containing the antirachitic factor.

The use of irradiated milk (fluid, dried, evaporated or condensed) is proving to be one of the important prophylactic developments of "activation." Of less importance is the activation of other foodstuffs (cereals, bread, etc.). A fact of broader interest than the prophylactic and curative value of irradiated milk is the clear demonstration of the superior clinical effectiveness of irradiated milk to cod liver oil and to viosterol (irradiated ergosterol) as well as to the milk from cows fed irradiated yeast. It would seem that the effect of irradiating milk with ultra-violet rays is to produce a substance of peculiar efficacy in the treatment of human rickets. Perhaps the combination of pro-vitamin D with the milk proteins may enhance the usual effect of irradiation on this sterol.

Photodynamic or Optical Sensitization (Harmful Effects of Sunlight)

It is possible to sensitize living cells, just as one sensitizes a photographic plate, and produce an abnormal condition in which luminous rays are as active as ultra-violet. This is photodynamic or optical sensitization. Most of the substances which act as sensitizers are fluorescent, but photodynamic action is not proportional to the degree of fluorescence, and while fluorescence is the usual accompaniment it is not the fundamental cause of the sensitization. The presence of oxygen is necessary for most of the effects produced by light, and the wavelengths which are effective are those absorbed by the sensitizer.

Photodynamic sensitizers arising under physiological as well as pathological conditions are capable, in the presence of light, of destroying both warm- and cold-blooded animals. There are illnesses which affect man and animals when they are exposed to light, either because the light is very strong or on account of increased sensibility, owing to the presence of a sensitizer or sensitizers. These may be exogenous, getting into the organism with the food, or endogenous, produced by the organism itself. Life can be wiped out by light and has been observed in organisms from man to the lowest.

The usual meaning attached to photodynamic sensitization is the production by luminous rays plus a sensitizer of the same reaction that ordinarily takes place under ultra-violet. A very considerable difference, however, exists; whereas the ultra-violet effects can occur either in the presence or absence of molecular oxygen, the photodynamic effects occur only in the presence of oxygen. Sensitization, however, may also be induced in the ultra-violet.

Pathologic conditions produced by sensitization in lower animals are the buckwheat sickness in cattle, the condition seen in sheep after eating St. John's wort and the clover sickness of horses and cattle.

Amongst conditions found in man presumably or possibly due to endogenous sensitization are the following: *hydroa estivale* or *vacciniforme, eczema solare, prurigo estivale* or summer prurigo, *xeroderma pigmentosum, urticaria solaris,* sailor's or farmer's skin, skin cancer, *lupus erythematodes discoides.*

Prolonged exposure to the violet and ultra-violet rays of sunlight or of artificial sources may cause not only systemic disturbances but also inflammatory and degenerative changes in the skin, varying with the person. The harmful systemic effects have not been well understood, but

deaths of infants following short exposures to ultra-violet radiation have been reported (Greenbaum). Hausmann also sounds a warning against the dangers of overindulgence in radiation. He believes that nowadays there is little danger that people on the whole are getting too little sunshine, but rather that they get too much, and that this is going to give rise to a number of acute and chronic pathologic conditions, if these are not present already. He is convinced that the central nervous system, especially the brain, must be injured by the over-irradiation and resultant heating of the skull. Furthermore, although the skin may become accustomed to sunlight, its action on certain parts of the skin results in a predisposition to certain conditions. An outstanding example is the well-known reddening of the chest of women, designated by Brocq as *"Dermatose du triangle sternoclaviculaire."* This conditions a *locus minoris resistentiae* for several skin diseases, such as acne, urticaria and eczema, which, if not due directly to the action of light, are indirectly so. Klare has called attention to a febrile bronchitis manifesting itself in some children, usually of light complexion with hair of a slight reddish tone. The skin reacts with inflammation and burning, not with pigment formation.

The Action of Sunlight on Tuberculosis

Heliotherapy has enjoyed two triumphs—the cure and prevention of rickets and its action as an auxiliary in the treatment of extrapulmonary tuberculosis—but there are numerous points in the latter which are far from settled. The results obtained, especially in bone tuberculosis, by a treatment régime, in which heliotherapy in the form of the complete sun bath is one of the factors employed, are impressive. But, while heliotherapy undoubtedly plays a large part in the results it is only a part, not the whole, of the régime. It is at present impossible to evaluate the other factors such as: exposure to dry and pure air, freedom from fog, dust, winds and rain, combined with ideal conditions of feeding, prolonged periods of rest, orthopedic treatment and, wherever possible, pleasant occupational therapy. These, in themselves, must play a large part in the excellent clinical results obtained.

Numerous contra-indications have been advanced to heliotherapy in phthisis, but the only valid one is met with in all localizations of the disease. When a patient is very weak, with much toxemia and hectic fever, the sun bath is liable to do more harm than good, and should therefore be deferred with the hope that rest and fresh air will strengthen the patient sufficiently for insolation to be justifiable at a later date. The combination of hot air and sun is bad for any form of tuberculosis, though particularly dangerous in the pulmonary variety.

For the extrapulmonary forms of tuberculosis physicotherapeutic measures often prove valuable adjuvants, but they are never to be employed to the exclusion of rest and hygienic-dietetic, and perhaps surgical, measures. Light in any form by itself is not curative but may prove an important aid. To believe that light by itself will cure tuberculosis, to be unduly optimistic about its effects and consider it a specific form of treatment, or to use it without sound medical advice and employ it to the exclusion of rest, hygiene and diet, eliminating orthopedic measures or the occasional necessary surgical intervention in bone and joint tuberculosis, is bound to bring criticism to an otherwise eminently desirable method of treatment. —*Mayer.*

The dangers of heliotherapy to be uninitiated tuberculid should not be treated lightly.

The sun is a powerful agent, and as a therapeutic instrument it is powerful for good, now widely known, but it is equally, or in even a greater degree, powerful for harm which is not so generally understood. For much of the abuse

of heliotherapy physicians have no direct responsibility. The idea that sunlight will cure tuberculosis is one admirably adapted to win popular acceptance, since it fits in so perfectly with well known facts, and is in itself so immensely attractive. Nearly everybody has heard of the idea, or known some one else who has heard of it, so that it is hardly in the least surprising that a man who finds himself infected with the disease should begin at once to bare himself to the sun. Many persons are doing it to-day, without the advice of a physician, with no knowledge as to whether it is indicated in the particular case, or as to how, if it were indicated, it should be gone about. A man with a violent infection in both lungs will think nothing of exposing the entire surface of his body, the chest included, to a combination of bright sun and hot, humid air. The result is that an alarming number of patients, under the influence of misinformation or incomplete information, are in this way jeopardizing their lives or even putting themselves definitely beyond the hope of cure. But the abuse of heliotherapy is not confined to the lay public. Within the limits of the medical profession the subject is not so generally or so fully understood as it ought to be. This fact is not surprising; indeed, it may be readily explained. Comparatively few physicians have occasion to make use of heliotherapy in their practice, and those who do not, having no special incentive to acquaint themselves with the treatment, are likely to entertain wrong notions regarding it not greatly different from those entertained by persons outside the profession.—*Watson.*

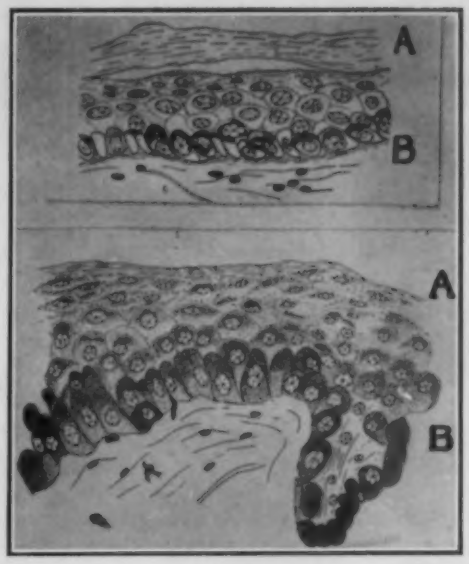


FIG. 5. *Upper:* DRAWING OF A SECTION OF THE EPIDERMIS OF A BLONDE ("CROSS BETWEEN BLONDE AND BRUNETTE"). IN LIGHTER BLONDES, FEWER BASAL CELLS CONTAIN STILL FEWER GRANULES; IN DARKER BRUNETTES THE BASAL CELLS CONTAIN MORE GRANULES. (*a*) HORNY LAYER; (*b*) BASAL LAYER. *Lower:* DRAWING OF AN UNSTAINED SECTION OF NEGRO SKIN, SHOWING THE DISTRIBUTION OF THE PIGMENT GRANULES IN THE EPIDERMIS. (*a*) HORNY LAYER; (*b*) BASAL LAYER. (JORDAN.)

Many specialists feel that heliotherapy constitutes a valuable aid to the fresh air cure in the treatment of pulmonary tuberculosis; furthermore, that it can be practiced everywhere, particularly favorably at the seashore or mountains, but best carried out in the climate most suitable to each individual case. On the other hand, many feel that its results are "not likely to be spectacular and its omission not detrimental to the patient's best interest" (Laird).

CONCLUSION

The number of human ills and abnormalities for which radiant energy, as emitted by the sun, carbon arcs and quartz mercury vapor lamps, is specific or adjuvant is small, much smaller than the number for which claims are made by manufacturers of lamps as well as by members of the medical profession.

Ultra-violet rays (shorter than 313 millimicrons) are specific in the cure and prevention of rickets (infantile and adult) and of infantile tetany.

Cases of extrapulmonary tuberculosis, including lupus vulgaris as a skin disease, are markedly benefited by careful exposure to sunlight or to the closest approximation to natural sunlight; *viz.*, the energy emitted by a flaming carbon arc lamp. The benefits are due not solely to ultra-violet rays, either those specific in rickets or somewhat longer, but as well

to the light or luminous rays and to the heat or infra-red rays, which are so preponderatingly present in natural sunshine and carbon arc radiation. The reports of the results with the quartz mercury vapor lamp in the treatment of extrapulmonary tuberculosis are disappointing.

Natural sunlight will hasten the healing of sluggish, indolent wounds. This effect, however, is certainly not a specific effect of short ultra-violet rays. The effect is a deep one, indirectly through the circulation, and is brought about by wave-lengths that penetrate through the epidermis and part of the dermis. The surface action of ultra-violet wave lengths shorter than 315 millimicrons in large quantity is detrimental to the healing of wounds, unfavorably influencing the processes of repair. The influence is due to the longer ultra-violet, luminous and infra-red rays.

Ultra-violet rays alone do not lower blood pressure, but flaming carbon arc radiation does—that is to say, of a certain percentage (between 60 and 70) of persons with abnormally high blood pressure. Both systolic and diastolic pressure may be materially reduced (from 10 to 15 per cent.) by general carbon arc irradiation, given in erythema-producing doses, not too frequently repeated, so as to avoid adaptation. The "cure" is temporary, and the treatments have to be repeated, being given every ten days or two weeks in those whose pressure has been lowered by earlier more often repeated large doses (usually every fourth or fifth day).

Among diseases of the skin *lupus vulgaris* is the only one on which ultra-violet rays act specifically. In others it may have favorable action, but the improvement is not specific, and in others exposure to such rays may cause or provoke an attack.

Owing to the hypersensitivity of many infants and adults caution should be used in the use of sunlight, both natural and artificial. Over-indulgence, even in the normal, is foolhardy.

IN QUEST OF GORILLAS

VI. FAREWELL TO THE GREAT LAKES

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

At last we were ready to break camp and take leave of our kind friends at Tschibinda, especially M. and Mme. Vierstraet and M. and Mme. Jooris, who were always so courteous and hospitable to us. Thus we were ready to start on our long journey from Lake Kivu southward to Albertville on Lake Tanganyika, thence westward by rail to the Lualaba River, thence alternately by boat and train north to the Congo, then down the Congo to its mouth, thence northwestward to West Africa. This journey took us from September 19, when we left Tschibinda, to November 14, when we arrived at Ozoum in the French Cameroon.

It can readily be imagined that four men, with four native servants, living for six weeks at one spot, had unpacked and scattered around about every one of the thousand and one articles in our possession. There were therefore hectic times trying to fit the parts of a host of three-dimensional puzzle pictures into boxes, bags, etc., each of the right size for one porter's head. It may also be imagined how eagerly all the small boys in the neighborhood, including our blond-haired little friends, the sons of M. and Mme. Jooris, hung around and eagerly received numerous presents of red negative ribbons, empty negative spools and other junk. It need hardly be said of the old men, who stood around hopefully like vultures, that their appetite for discarded wooden boxes and tin cans was simply wolfish and that they grabbed and snatched things with frenzy.

McGregor and Engle, who walked down to Bukavu, taking with them part of our equipment, were the first to take leave of this delightful spot, where the thermometer seldom rose above 70 degrees Fahrenheit. We recalled that letters from home had spoken commiseratingly of the "awful heat in Africa," and that we had read them at night, sitting up snugly in our beds under three blankets and with woolen sweaters on! But now we were really going to face the music in the alleged steaming forest of Du Chaillu's gorillas.

Well, farewell, Tschibinda! We'll carry with us innumerable memories of your glorious mountains and titanic clouds, and especially of the elusive and shaggy man-beasts of your leafy groves.

We left Tschibinda on a bright moonlight night and took a short path down the open mountainside to Mulungu, while the porters went around by the road. It was highly exhilarating to go quickly and lightly down this path, to see the dark-gray, wave-like mountains in the moonlight and to be guided to our goal, the village of Mulungu, by a single star-like light standing out against the mountains.

We arrived there late in the evening, expecting to find the ox-cart with the gorilla, together with the camion that was to take us to Bukavu. But we were told that the pole of the ox-cart had broken along the road and that porters had already been sent by our good friends in Mulungu to carry the gorilla the rest of the way down the mountain.

Photograph by H. C. Raven

"GROUP IN BRONZE"

Sketch from author's notebook

SUNRISE ON LAKE KIVU

The camion was there in front of its shed, ready to start early next morning. We accordingly spread our bed-rolls on a cleared field alongside the road and would have passed a very comfortable night had it not been for several interruptions. First, one of the thatched native huts near by caught fire and soon several of them were burning fiercely. The people were taking it in very good part and were not a bit more vociferous than usual, their black bodies making an interesting scene as they moved about in the light of the fire. One of the houses was near the garage where gas and oil were kept, and we didn't quite like the idea of that, so Raven wakened the driver of the camion, who directed the natives to tear down the house next to the garage, that building being protected by its corrugated roof and wall.

The next diversion was caused an hour or so later by the arrival of the gang of porters bearing the body of the gorilla, which was duly deposited in the camion. In the flickering light of the campfire they looked like a choice collection of cannibals, but we knew they were innocent farm hands. Then there was a great outburst of jabbering while Raven lined up the gang and paid not only the porters but the several alleged headmen and policemen and assistants who, they assured us in thousands of words, had rounded the porters up to go after the gorilla. Then all settled down quietly for a couple of hours until 5 A. M., when we and our boys arose, rolled up our bed-rolls, put them on the camion and climbed aboard ourselves, getting under way before daylight, at 5:30.

Much as I disapprove of such early rising, I was well recompensed by the scenes that began to unroll themselves as we zigzagged down the rocky mountain road. In a little while we came to a sharp down grade. On either side of the road opened out great pyramidal masses of contrasting deep shadows and intense lights, the latter from our camion headlights, the former from the immense mountains verging steeply downward in front of us. Near the bottom of the picture, where the shadows were blackest, a single spot of glowing red was caused by the embers of a small wood-fire.

After winding down grade for some time we came within sight of the lake. The golden-red sun was just piercing the heaped-up cumulus clouds and beginning to rise above the tops of the mountains on the other side. Here was a scene of glinting water, of mountain silhouettes in purplish gray shadows and of a lone twisted tree on a near-by promontory. We stopped a few moments and I got a hasty sketch of the scene, which I filled in later.

We arrived at Bukavu at 7:30 A. M. and found McGregor and Engle at the hotel there. I took a last glance northward at our old neighbor Mt. Kahusi, still standing guard over beautiful Tschibinda; then I found a niche in the pile of baggage on the camion and we started south on the return journey to Uvira at the head of Lake Tanganyika. Soon we were climbing the reddish mountains south of Bukavu and could look down on our left at the silvery trail of the Ruzizi River, winding between the hills where it exits from Lake Kivu. These bare hills were dotted with small groups of cattle, one of which that we peered at through our field glasses had the longest horns I saw in Africa.

After a long time we came to the gray volcanic cones that have been the focus of titanic forces of uplift, which in times geologically very recent have broken up the whole region and exposed beautifully fresh sections of deep Archean rock.

The immensity and wildness at the peak of these stirring scenes were rather lessened by the presence of hundreds of noisy blacks at work on this great highway, which is constantly being improved

by the Bullamatari or "rock blasters." This name, by the way, was originally applied by the Congo natives to Henry M. Stanley, who once used dynamite to blast his way through some obstacle to navigation in a river; but the Belgians, who are his legal and spiritual heirs, worthily inherit also this name. At this point the blacks swarmed like ants, but shamed the latter for wasting energy in running uselessly about. The blacks indeed are at all times masters of the shortest effective distance between the two points where a rock has to be picked up and cast down; when a man has to do this all day long, economy of effort is a sign of foresight and prudence, and no one who has watched the patient blacks carry heavy loads on their heads up steep mountain paths can deny that they are also capable of long and well-sustained action.

Gradually we descended from these precipitous heights to the open country that slopes gently down to the northern end of Lake Tanganyika. Here the erratic Ruzizi River seemed to wander around in a rather aimless way, not going through a deep valley of its own but rambling over very shallow and hastily improvised beds. Once we crossed a bridge over a newly cut bank and one could see that this region had received a lot of gravelly alluvial deposits in comparatively recent times, doubtless since the last great uplift to the north, which had increased the scouring power of the Ruzizi and perhaps caused it frequently to choke up its old beds and overflow into new courses. The Encyclopedia Britannica (Art. Tanganyika) states that the Ruzizi River only reached the north end of Lake Tanganyika in 1906; but before that the river for a long period of relatively dry seasons may possibly have seeped into its own earlier gravelly deposits at the north end of the lake; anyhow we may be sure that the

Photograph by H. C. Raven

WAITING FOR CUSTOMERS. BUKAVU MARKET

Photograph by H. C. Raven
AFRICAN FLAPPERS

Photograph by H. C. Raven
A SOLDIER'S WIFE

present great elevation of Lake Kivu above Lake Tanganyika is a comparatively recent event, probably contemporaneous with the volcanic uplift to the south of it, and that the present Ruzizi valley is quite young.

At the ford of the Ruzizi, not far north of Luvunghi, we recalled an amusing incident that had happened at this spot. Several years ago Mr. Stephenson of Bukavu had just passed across this ford in an ox-cart drawn by many oxen. He had outspanned the oxen, which were grazing about quietly, while he was seated in the cart, dozing after luncheon. Suddenly a good-sized herd of elephants appeared on the other side and forded the stream just at this point. They swept past the ox-cart, paying no attention to its occupant, and as he had no gun with him he did not feel at all hurt by their neglect. The cattle never even lifted their heads and fortunately went right on browsing as if nothing had happened. He was beginning to breathe more freely when a young bull elephant, who had tarried a little behind the others, discovered him and showed signs of nervousness, lifting his trunk and apparently preparing to charge. The old ones, however, were moving ahead and on second thought the young one seemed almost to realize that he would only be making a fool of himself by upsetting a harmless ox-cart. At any rate, he hastened after the others and Mr. Stephenson got down and inspanned his oxen.

At Uvira we had as usual to wait several days for the next boat to Albertville on Lake Tanganyika, but we naturally shunned the "Greek Hotel" with its memories of mbusi (goat's meat) and applied for admission to the so-called English hotel. No cottages were vacant, but the manager kindly allowed us to set up our sleeping tents in the open yard of the hotel; there we were very comfortable, while good meals were served in the open-air dining-room, facing the great lake. A new hotel, of brick, was being built on these grounds in anticipation of

Photograph by H. C. Raven

GUARDING HER HUSBAND'S WARES

the new railroad running along Lake Tanganyika and Lake Kivu. The black bricklayers and mortar-mixers might have qualified as the world's low-speed champions, but the new hotel, like the railroad itself, was growing as the great nests of the termites grow, through the summation of almost infinitesimally small increments of individual effort.

During this time of waiting Dr. Engle and I went several times to the Swedish Lutheran Mission a few kilometers north of Uvira, where through the kindness of the Reverend Mr. Windberg and his colleague, Mr. Carlsson, we secured footprints and height measurements of eighty people, including men, women and children. One of these natives was a youth with the longest arms and shortest legs I have ever seen on a human being, since his width across his outstretched palms considerably exceeded his standing height. Some of the people had splendid wide flat noses of what I called the three-bulb type, that is, with one median and two lateral bulbs in nearly the same plane. The missionaries and their families were cultured and pleasant people, who lived in a large white house overlooking the lake. From their broad verandah with its stately wooden columns we had a fine view of the northern end of the lake. There in the old days many hippopotami disported; but now, our hosts told us, only a solitary old bull still hides in the reeds. On several occasions the missionaries very hospitably entertained us, and it was a genuine pleasure to sit down to a table with spotless linen, fine china and excellent food. One of their guests, a Swedish gentleman who had been an officer in the Belgian colonial army, spoke of the Belgians' humane policy of forbidding the use of the lash on the natives. He added that this sometimes had its practical disadvantages, as in the case of an unruly black boy who had deliberately smashed

Photograph by H. C. Raven

NATIVES PREPARING COFFEE AT A KIVU MISSION

a second large and beautiful china dish just because he had been fined for breaking a first one.

On the way home from the mission one day we saw in the distance several women and children surrounding a cylindrical wooden vessel. Each one had a long post in her hands and took her turn in lifting it up and smashing it down on the grain in the vessel. Merrily the posts shot up and down like pistons on a crank-shaft and, one is tempted to say, almost as fast.

While at Uvira I again indulged my habit of wandering about the open hills and along the shore of the lake. The yellowish-gray crystalline mountains that crowded the lake shore were peculiarly satisfying, partly because they gave me a glimpse of rocks of incredible antiquity but which had only recently been pushed up from the depths so that the forces of erosion could expose them. Viewed in front they were like superimposed alternative rows of inverted V's with widely spread slopes and with apices rounded off. Seen in profile against the sky just before dusk they ran down to the lake shore in bold jagged masses of dark purple. Their contours were evidently produced by the present erosion or drainage system, dating back perhaps only a few hundred thousand years, but their rocks had been crystallized at great depths possibly a thousand million years ago, long eons before the dawn of living matter.

On September 25 we broke camp at Uvira and sent our luggage to the steamer wharf near by at the small village called Kalundu. Here a creek comes out through a fine gorge between steep and imposing masses of crystalline rock. As the steamer we were to take was still far out on the lake, I could not resist the temptation to wander a little way up this gorge to admire the drab mountain masses, often blackened by bush fires or

splashed with yellowish brown and olive patches. Here and there brilliant red flowers on flamboyant trees stood out from the somber background. Looking over the lake I could see the *Baron d'Hanis* in the distance and behind her a rain cloud rolling toward us. Soon there was a fine display of lightning and a few big drops, which eventually became a downpour. For a while I stood on the recumbent trunk of a large tree with extremely broad leaves and watched both the rain and the ants narrowly. The big leaves served as an umbrella until the downpour came. Then I broke cover and dashed down the hill, arriving just before the *Baron d'Hanis* touched the wharf, fairly wet but with some glowing memories of my last ramble among these strange exotic scenes.

At the wharf we each gave a farewell present to Behongo, our sleek-looking boy with the beautiful teeth, whose smiles cheered our departure. The other three boys elected to go with us into the unknown world, but Behongo sensibly enough chose to stay with his wife in his home town.

As we sailed southward near the west shore of the lake we saw that the type of bluntly serrate crystalline mountains with which we had been familiar at Uvira extended parallel to our course and for a long distance southward along the western shore, but as we receded from the great disturbance which had produced the jagged mountains south of Lake Kivu, the height and boldness of the peaks sensibly decreased.

At one place we passed a tiny rocky island near the shore, which had been named "New York Herald Island" by Henry M. Stanley, in memory of James Gordon Bennett's part in sending him to rescue Livingstone. During the greater part of our journey in Africa we had been and would be going over part of Stanley's routes, from the east coast across the rift valley to Lake Tanganyika, thence westward to the Congo, down the Congo to Stanley Pool, and so on to the coast. But while we went in trains, automobiles and great river steamboats, he had traveled on foot, often in spite of hostile tribes who tried to block his advance. Such is the contrast between the Africa of to-day and the classical Africa of the great explorers.

After some hours of steaming we touched at Baraca; this lies in a deep bay, flanked by a high ridge called Burton Promontory, which juts out obliquely into the lake for many miles. This promontory reminds one of the long mountainous island of Kwidjwi in Lake Kivu. It would seem that the horizontal tension which caused the great rift in the rocky plateau had been resisted perhaps by the rock of the Burton Promontory, so that the rifting force had divided into two very unequal parts, the greater part producing the main valley that is now filled by Lake Tanganyika, the lesser fork becoming the bay of Baraca. The hills of this promontory have been worn down so that they have lost their serrate tips and present only a slightly irregular skyline; in other words, this seems to be a relatively ancient or mature drainage system and the land may have escaped any marked uplift in relatively recent times, which would have rejuvenated erosion and produced deep valleys and serrate peaks.

In a canoe near the wharf at Baraca was a little boy, one of those who were diving for coins thrown out by the passengers, who proved to be one of those individuals whose face one never forgets. It reminded me of the large-eyed portrait masks that the Egyptians used to put on their royal coffins. Never have I seen such an imposing large face or such enormous eyes. It is true that we had seen many large-eyed Negroes around the south end of Lake Kivu and the north end of Lake Tanganyika, but in this beautiful boy the character seemed to reach its climax.

Another thing of special interest at

Photograph by H. C. Raven

BELGIAN HIGHWAY OVER THE MOUNTAINS SOUTH OF LAKE KIVU

this point was the presence in the water of many small jellyfishes, which, being closely related to marine types, are regarded by some zoologists as souvenirs of a very distant time when the great Rift system had an opening to the sea at its southern end below the Zambesi River.

We then steamed northeast, rounded the tip of Burton Promontory and headed southeast for Kigoma.

To summarize at this point my observations on the contours of the mountains, it may be said that as we passed southward the mountains gradually became worn down into low hills and one could see many intermediate stages in this process of degradation, from stretches south of Uvira, where the drainage slopes of the mountains resembled a system of inverted V's superposed one above the other, to the other extreme of Kigoma, where the limbs of the V were opened out very widely and the top rounded off so that only a low convexity remained.

As we had to wait for a night and a day at Kigoma, all four of us walked out to the "elephant's foot" rocks and netted a few of the bats there as they flew out of their cave. McGregor got some interesting cinema records of these animals, which had enormous ears like those of a jack-rabbit and pointed muzzles. A huge baby clung to the nipples of one bat. On the way along the lake shore Engle picked up a large thin cycloid fish scale, which reminded me somewhat of a tarpon scale. The identity of this fish puzzled me a good deal and I shall presently relate how the puzzle was solved.

Late that afternoon I climbed one of the rounded high hills back of Kigoma, following a winding path which led past plowed or empty fields to the crest. A small leaping mammal[1] easily escaped me. A few perfectly gigantic ants were safe from any interference from me.

[1] It was probably one of the "jumping shrews."

The dried dung of a large carnivore, possibly a hyena, added another African touch to the day. Looking west from near the top of the crest, I had a fine view of the rocky promontories, including the "elephant's foot," that guarded the bay of Kigoma, and a little later I faced the crimson sunset.

At the very crest of the long hill was an abandoned native village, which just before dusk was haunted with an uncanny stillness. Why had the people abandoned such good houses? If sleeping sickness had grievously afflicted the people, would not the government have burned the houses? Had the chief died and had the witch-doctors then declared the village itself taboo? But there was no time for further reflections. I gave one glance down the long hill on the other side of the crest to a vast open rolling country dotted with trees but with no visible signs of human habitation, then turned and hurriedly descended the long hill to our ship.

During the night the *Baron d'Hanis* crossed the lake and landed us the next morning at Albertville. As we steamed toward the bay we could see a system of diminutive mountains behind the town, perfect pygmies in fact, but nevertheless in a fully adult, not to say senile stage of development. For their little inverted V's still retained clear evidence of having arisen through the erosion of mountain streams, but only the tops of the V's were worn down into the well-rounded convexities of old mountains. At one point I could see with my field glasses some oblique ledges of dark purplish-red stone, which possibly belonged to the Lualaba system (Lower Permian).

Albertville is a very bustling and intensely modern little city with a long street of white hotels and shops along the bay and many smart-looking residences along the hilltops. When Mr. Raven was there ten years ago, about the only white man present was the Belgian administrator, who lived in a small house built by the natives. The town is the terminus of the railroad, which runs westward to Kabalo on the Lualaba River and is thus the outlet of the commerce of the Upper Congo.

Late that afternoon Raven and I walked northward a mile or two to the Lukuga River, which is the outlet of Lake Tanganyika and which he had studied ten years ago. This river is of interest because it seems to be relatively recent in origin. It is one of the small tributaries of the Lualaba or Upper Congo River and thus its waters flow west toward the Atlantic. There seem to be at least two possibilities as to the way this river arose. After the high plateau had split asunder, making the excessively deep cleft which is now filled by Lake Tanganyika, the waters naturally flowed into it. Sooner or later the southern exit was pinched off by further earth movements and the deep cleft filled up until it began to spill over at a certain point and thus gave rise directly to the Lukuga River. The small gorge through which this river passes would thus have been worn down by this river alone. A second and perhaps less probable hypothesis is that the gorge of the Lukuga has been worn down through the cooperation of two streams, one flowing east into the lake, the other flowing west to the Lualaba River. Under certain circumstances the headwaters of one side might capture those of the other, and both systems might then cooperate in cutting down the watershed between them, which is now represented by the present gorge.

When Mr. Raven was at this place ten years ago, he and his colleague, Dr. Shonts, made a series of rough measurements of the run-off of this river by timing the average rate of the current and multiplying it by the area of the cross-section, which they obtained by soundings at various points. The amount of

Sketch from author's notebook

DRAINAGE SLOPES ON WEST SHORE OF LAKE TANGANYIKA, SOUTH OF UVIRA, WITH NEW YORK HERALD ISLAND IN THE FOREGROUND.

water drained from Lake Tanganyika by this river is not great, but as time goes on it will probably slowly increase. However, the lake is in no immediate danger of being badly drained by this little nibble on its high wall, as it is 4,708 feet deep and it would take tens of thousands of years for the Lukuga to wear down its gorge to any appreciable extent.

Along the broad lake shore, near the Lukuga outlet, there was a wide sloping beach of fine sand, upon which were countless multitudes of old snail shells and pools of fresh water filled with tens of thousands of pollywogs—a typical example of both the almost incredible fertility of nature and the dominance of particular types in suitable places.

Before turning our faces forward to the new scenes that greeted us on entering the Congo basin, let us review briefly some of our outstanding impressions of East Africa and the great lake region. First, at Mombasa and Dar-es-Salaam on the east coast we had seen settlements where the Hamitic and Arabic influences on the Bantu Negroes had been very potent. Geologically this was on the strip of the coastal plain, with shell and coral rock that had been subjected to moderate elevations and depressions. Then on the railroad we had gone westward a little way to the escarpment on the edge of the enormous rocky plateau of inconceivable antiquity which forms the crystalline mass of central Africa and which has never been flooded by the ocean. Next we climbed the escarpment and began the long slope downward into the trough of the "great rift" system, which extends north and south from below the Zambesi up through the Red Sea to Palestine. Traversing the wide shallow depression of central Tanganyika, which is relieved by granite hills of majestic wildness and desolation, we had spiraled up the divide and then descended somewhat to the western or Albertine rift occupied by Lake Tanganyika and its northern relatives, Lake Kivu and Lake Albert. These owe their existence to great subterranean disturbances which forced certain great blocks upward, opened great rifts and allowed long strips to settle, while Lake Victoria was formed in a basin-like de-

pression perhaps corresponding to the basin of the Congo River (Bailey Willis).

Traveling north on Lake Tanganyika and then up the Ruzizi River to Lake Kivu, one of the highest lakes in the world, we had finally gone up into the mountains west of Lake Kivu, where at altitudes of 6,700 to 9,000 feet we had been on the "ridgepole" of the continent in this region. Now we had come away south, many hundreds of miles, and were about to go down the western side of the ridgepole into the Congo Basin. In connection with field notes and sketches of the Ruzizi River, which carries the overflow of Lake Kivu down 2,600 feet to Lake Tanganyika, I had become interested in the problem as to what had happened when the terrific displacements south of Lake Kivu had thrown a great barrier across the old Rift Valley.

In general, while we were in the region of the southern end of Lake Kivu and the northern end of Lake Tanganyika we had been among peoples which were apparently a mixture of the "cattle-keeping aristocracy" from the northeast, the forest Negroes, the pygmies, allied with those of the Congo Basin, and the Bantu Negroes of east Africa. Thus we had seen a part of the "melting-pot" of Africa, and it was therefore not surprising that these natives displayed an immense range of variability, both in anthropological measurements and in their personal individuality, examples of which have been given above.

In the mountains west of Lake Kivu we had been in the home of the eastern or Mountain Gorilla, an outpost of gorilla territory on the extreme eastern margin of the great forest, these gorillas being now widely separated from their western relatives, the gorillas of the Cameroons and the Gaboon of French Equatorial Africa.

We had found these gorillas to be extremely shy, retiring animals, wanting nothing so much as to be let alone and repelling the snooping advances of white busybodies. We had found them going in small roving bands of variable number, making their beds for the night under and in trees with spreading branches, and consuming a prodigious quantity of succulent vegetation. The big males had been quick to charge at the persistent hunter, and on the third charge a certain old male had been dropped only a few feet away from Raven's gun. Raven had secured two fine specimens, he had injected them with preservatives, they had been shipped to our anatomical laboratories in New York for further study and we had accumulated a good many observations on their habits.

All that we had seen so far was in harmony with a vast amount of other evidence that the gorilla has been a relatively late offshoot from the broad group of *Dryopitheci* or ancestral man-apes that gave rise also to the chimpanzee and to man; more specifically, that the gorilla represents a branch which has become specialized, by means of its cross-crested molar teeth and greatly enlarged abdomen, to eat enormous quantities of succulent vegetation, without, however, losing the essentially prehuman character of its digestive tract.

As the western shore of Lake Tanganyika is also the eastern limit of the Congo forest, at Albertville we were on the high outer margin of the Congo Basin. Hence it was not surprising to find the fishes of Lake Tanganyika closely related to those of the Congo system.

On the lake shore at Albertville, just about dusk one afternoon I came to a place where two gangs of men were starting to haul in a large seine. Eagerly I awaited the sight of the catch, which consisted mostly of fine large cichlids, like those I had seen in Lake Kivu. But one

THE MOUNTAIN GORILLA AT HOME

FROM A PAINTING BY ARTHUR JANSSON, UNDER DIRECTION OF H. C. RAVEN.

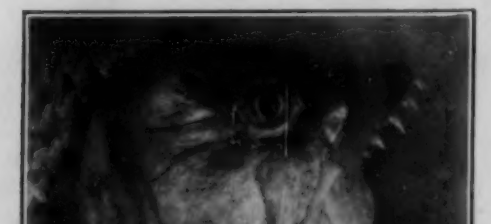
beautiful silver fish about ten inches long excited my cupidity and I promptly grabbed it. A Portuguese kindly told me in French that it was not much good, but I told him I was a student of fishes and that satisfied him. The owner asked four francs (twelve cents) for it, probably an exorbitant price, but I paid it without haggling and carried it off in triumph to the hotel, for it was one of the classical family of African characins, the first I had seen in Africa, although I had studied their skeletons at the museum. It was resplendent in large silver cycloid scales, which left no doubt of the identity of the single cycloid scale which we had picked up at Uvira. I made a rough sketch of it, which afterward showed that this fish was at least related to the genus *Alestes*. It had large eyes and small mouth studded with sharp little teeth arranged in vertical bands; its body was fusiform; the anal fin was elongate and it had the very wide tail and caudal peduncle of a powerful swimmer and quick snatcher of living prey. As all our preservatives were packed up and inaccessible, I had to give this silvery beauty away the next morning.

To the student of the evolution of

Photograph by Herbert Lang

AFRICAN RELATIVE OF THE "MAN-EATING FISH" OF SOUTH AMERICA.

fishes the African characins are of great interest. Their nearest allies are the famous piranhas, or man-eating fishes, of South America. The headquarters of the highly diversified family of characins is in South America and the presence of a few characins in Africa has been cited by those geologists and zoologists who believe that in former geologic ages there was a land bridge stretching across the Atlantic from South America to equatorial Africa. There is indeed a great deal of evidence for the reality of such a bridge in the present and past distribution of many forms of marine invertebrates, as recently reviewed by Professor Schuchert. It is also a curious fact that among the marine mammals the Florida manatee (*Trichechus manatus*) has a very close relative, *Trichechus senegalensis*, off the coast of Africa (Hatt, R. T., 1934); although manatees may be swept out to sea by storms, they are strictly herbivorous animals feeding on vegetation of rivers and estuaries, and there is no evidence that they could live through a transatlantic trip without food. The fossil snakes, chelonians and other extinct vertebrates of the Fayûm in Egypt, described by C. W. Andrews, were also cited by him in support of the well-known conclusion of the conchologist Von Ihering that a long archipelago at least stretched from the Amazon region to the Guinea coast. On the other hand, the paleontologist, W. D. Matthew, in his work on "Climate and Evolution" showed that the tapirs and many other mammals of South America had reached there by immigration from North America. In extending the principle of the northern origin of forms now found in the southern continents to all classes of vertebrates Matthew may have gone too far.



Photograph by Herbert Lang

HEAD OF *Hydrocyon*, LARGEST AND FIERCEST OF THE AFRICAN CHARACINS.

In any case, a recent comparative study of the skeletons of African and South American characins by the writer and his assistant, Mr. G. Miles Conrad, brings out clearly the very close relationship of these two lots of fishes, which are now separated by a wide ocean.

This characin of Lake Tanganyika was evidently allied with those of the Congo River, and its presence emphasized the fact that on the west shore of the lake, or at least in the hills back of it, one would be standing on the outer rim of the immense drainage basin of the Congo River, which we were to enter the next day.

(A further article in the series entitled "In Quest of Gorillas" will be printed next month.)

PLAYGROUND OF A SCIENTIST

By EVA V. ARMSTRONG

CURATOR OF THE EDGAR F. SMITH COLLECTION IN THE HISTORY OF CHEMISTRY, UNIVERSITY OF PENNSYLVANIA

Most of us come into this world with a pack on our back, invisible to the eyes of childhood, carried lightly through adolescence, but as the days pass the pack mysteriously increases in weight. No longer can we nonchalantly ignore it, so we decide to open it—to lighten it or to divest ourselves of it, if possible. Besides we are a bit curious by this time. We break the seal, and out steps a lively genie. We recognize him at once—just the same old genie we read about in Hans Andersen—by all the traditions he ought to let us make a magic wish. A gallant yacht? King Midas touch? A lovely lady? But the genie says nothing of wishing, and we stare a little as he hands us a violin or a scalpel, a pencil or a pick and shovel, architect's tools or a test-tube. And from that day our doom is sealed. We enter the world of work. Tempered with a little laughter and a little love, we find our days full, pleasantly so at times, unbearably so upon other occasions. We are jostled, praised, blamed, sought after, neglected, exploited, loved and hated. We continue to work. On a weary day, battered on the main highway and spent with the struggle, we enter a quiet street and open a door into a garden. Here are shrines laden with strange objects—butterflies, postage stamps, objects of wood, bronze and glass, strange hieroglyphics, pictures, manuscripts and old tomes. Before the shrines we see the devotees, seemingly rapt in the beatitude of angels. As we timidly approach an altar a curious old volume falls at our feet. Intrigued by a strange device on the cover, we pick it up. Its pages are stained, its print curious, its illustrations have a strange symbolism, its wormed pages make us realize that we have neglected to think about bookworms —does one ever actually see a bookworm, or only his work? Is he wholly anonymous? We turn the pages of our volume and ponder its age. A strange, unworldly peace descends upon us, there is a curious twitching in our fingers, we surreptitiously slip the book into our pocket and for better or for worse, in sickness or in health, we have become a book collector. True, we must leave the enchanted garden, we must eat, love and work—but we carefully mark the spot that we may return anon. We have found a way of escape, where at times we may in enchantment

> . . . lie buried,
> The world forgetting, by the world forgot.

It is said that the personality of the collector creates the life of the collection. Is it cold, colorful, vital, inspiring, stupid or inane? So perchance is the collector. It is well to know him before engaging to view his treasures.

Dr. Edgar Fahs Smith, whose collection of rare books, prints and manuscripts pertaining to the history of chemistry is the subject of this sketch, was born in York, Pennsylvania, in 1854. Educationally he was a product of the old-fashioned curriculum, consisting of Latin, Greek and the humanities. At the age of sixteen he taught Latin. This training stood him in good stead, when later at the University of Göttingen, in Germany, he was required to write his doctoral thesis in Latin, to defend its grammatical construction and chemical content in German before the assembled faculty, himself arrayed in evening dress, white gloves and high silk hat.

Edgar F. Smith
5/25/1926

Possessed of an inherent love of books, as a boy he supplemented the single volume which he received each year at Christmas by his own purchases, made as a result of strenuous toil in loading coal wagons, working on a farm during vacation periods and finally as a printer's devil. Here he learned to set type and to print with an old-fashioned hand press. The art of printing attracted him, and he acquired in time an appreciation of fine typography. At the age of seventeen, he became publisher and editor of an amateur paper entitled *Our Effort*—"printed every month at the low rate of 50 cents a year, in advance." He wrote the articles under various noms-de-plume, set the type, printed the journal, which he then proceeded to sell in a house-to-house canvass. Its early demise occurred upon a day when the publisher was unable to pay for the paper required for a forthcoming edition.

As a boy, Dr. Smith longed for the books of Oliver Optic and of Captain Mayne Reid, desires infrequently attainable by him. It is interesting to note that later in his career, in a secret recess of an old-fashioned desk from which he administered the affairs of a great university, there reposed—unknown to the serious and august members of the faculty who visited him—a collection of Mayne Reid and Oliver Optic books. Dr. Smith always referred to them as "my boy books" and was guilty on rare Saturday afternoons of leafing them over. It was a secret joy which he had.

Educator, chemist, author and provost of the University of Pennsylvania, Dr. Smith found little time for holiday or recreation. He believed in the doctrine that "it is better to wear out than to rust out," and said that rest came to him through change of work. He referred to the collection of rare books and prints which he assembled as a "playground of the mind." He entered this playground with the pure and unalloyed pleasure of a child in a toyshop. Administrative worries, abstruse scientific problems, personal cares forgotten, he wandered about, happy and enthralled, with the immortals of his science. A sympathetic and understanding friend of man, he entered the minds and hearts of the philosophers of long ago. They spoke to him through yellowed pages. He grew in intimate knowledge of them and their work.

With the alchemists, Dr. Smith sought the philosopher's stone, the transmutation of metals, the elixir of life. In weird cellars and old laboratories he shared their failures and successes, their comedies and tragedies. In a Benedictine monastery he discusses with Basil Valentine "The Triumphial Chariot of Antimony," and gently chides him for his penchant for antimony as a nostrum, reflecting upon the legend that it derives its name from the fatal effect it had when used as a medicine upon the unfortunate friars (anti-monk); with the honest old alchemist, John Dee, he meets Queen Elizabeth and journeys with Dee and his rogue friend, Edward Kelley, to the Court of King Rudolph II of Bohemia, where gold is sought by transmutation in a little street which may be seen today by visitors to Prague. Dee returns to England, but the death of the villain in the piece, Edward Kelley, in a fall while trying to escape from a tower where he has been imprisoned by the King for his deceptions, seems an act of good old-fashioned justice. True, there are those who scoff at alchemy, but the preface in an old book assures Dr. Smith that "alchemy is indeed the mother of chemistry, and it is not the daughter's fault if the mother is absurd." Interested and amused by the bombastic Paracelsus, who says that the true purpose of chemistry is to make medicine and not gold, Dr. Smith reflects upon the vanity of man. The chemical oven of Leonardo da Vinci intrigues him, as do the experiments of Roger Bacon on the making of gunpowder. He listens to the

ROBERT BOYLE, 1627–1691

ENGLISH CHEMIST AND EXPERIMENTAL PHILOSOPHER. A FOUNDER OF THE ROYAL SOCIETY. "MR. BOYLE, THE ORNAMENT OF HIS AGE AND COUNTRY. . . . WHICH OF MR. BOYLE'S WRITINGS SHALL I RECOMMEND? ALL OF THEM. TO HIM WE OWE THE SECRET OF THE FIRE, AIR, WATER, ANIMALS, VEGETABLES, FOSSILS: SO THAT FROM HIS WORKS MAY BE DEDUCED THE WHOLE SYSTEM OF NATURAL KNOWLEDGE."—BOERHAAVE. REPRODUCED FROM AN ENGRAVING BY GEORGE VERTUE, 1739, IN THE EDGAR FAHS SMITH MEMORIAL COLLECTION, UNIVERSITY OF PENNSYLVANIA.

conversation of Robert Boyle with Dr. Harvey on the circulation of the blood. He enters the bowels of the earth with Agricola to study mining and metallurgy with that sturdy soul, who, despite his great achievements and his gratuitous care of the sick in the village in which he lived, upon dying was refused a resting place there because of his religious views. And Dr. Smith muses upon the thought that three hundred and fifty years later, Agricola's *De re Metallica* (1556), the most important contribution to metallurgy for a century of time, should find new life in English dress at the hands of a twentieth century mining engineer and President of the United States of America, with the scholarly assistance of the first lady of the land. With Joseph Priestley, the discoverer of oxygen, he lives through the riots at Birmingham, England; Priestley's emigration to America, his friendship with Franklin, Washington, Jefferson, and his fundamental contributions to science in America. He mourns for the ill-fated Lavoisier, who overthrew the doctrine of phlogiston, so staunchly supported by Priestley, and who brilliantly established the foundations of modern chemistry, only to be denounced by the mob of the French revolution, and lost to his young wife on the guillotine on the same day that her father was executed. Galvani's experiments in electricity recall to him Dr. Harvey Cushing's note in Osler's Catalogue: "Who, says Helmholtz, when Galvani touched the muscles of a frog with different metals, and noticed their contraction could have dreamt that all Europe would be traversed with wires, flashing intelligence from Madrid to St. Petersburg with the speed of lightning? . . ."

Is it strange that Dr. Smith returned from these marvels to the everyday world with eyes alight, inspiration in his heart and a consuming, burning ambition to introduce his old friends to his new friends. This he did in informal talks which held his audiences under a spell from which they awakened only with the closing word, and in a series of delightful essays and books in which he put flesh upon the skeletons of the pioneers of the science, making them living, breathing personalities. Surely, at journey's end these friends of the long-ago awaited eagerly to greet him as one known to them and dearly loved for his remembrance of their deeds. Eternity can not be long enough for all that must be said.

One of Dr. Smith's peculiarities as a collector was his refusal to have a card catalogue of his treasures; he would as soon have thought of making a card catalogue of his friends. No unsightly library number must deface them—he knew his books and pictures. If he placed one of them on a shelf he could go to it weeks, even months later, and put his hand upon it. One of his characteristics was a remarkable and somewhat uncanny memory for books and for people. Alumni of the University of Pennsylvania, returning after an absence of many years, had only to appear in the ever-open doorway to be called by their first names. A favorite sport at alumni reunions of ten or twenty years was to line up and be recognized by "the Doctor." He seldom failed. His sincere and friendly interest in young men led President Thwing, of Western Reserve University, to call him "the best-beloved college president of his generation."

The cost of books in the field of old chemistry was comparatively low when Dr. Smith began to collect them. It has increased materially since other scientists have fallen from grace, but not to the point where a poor but honest college professor may not pick up a few examples in early science without placing his family upon the dole. Pencil in hand, Dr. Smith carefully scanned the magic catalogues. Representing the university abroad at stately functions, he yet found time to haunt old book shops—Berlin, Munich, London, Paris, Milan and Rome —all knew his happy, eager quest.

The story of the beginning of his collection is best told in his own words, written in 1921:

> My interest in the history of chemistry began more than 30 years ago. . . . As a student, the time honored volumes on the history of chemistry had been dutifully read by me, but with shame I confess that over many of these volumes I fell fast asleep. Yet when the life story of the makers of our science came to me, then quite a different attitude towards its history was awakened in me. . . . I took to visiting out of the way second hand book-shops—usually on Saturday afternoons, picking up here and there a stray volume devoted to chemistry. The first pamphlet I purchased, costing ten cents, contained something about the compound blowpipe. There was a well defined picture of a piece of apparatus in it. Some obsolete cumbersome form of apparatus that someone—at some time —had printed. To him doubtless it was

A PAGE FROM BOYLE'S BOOK

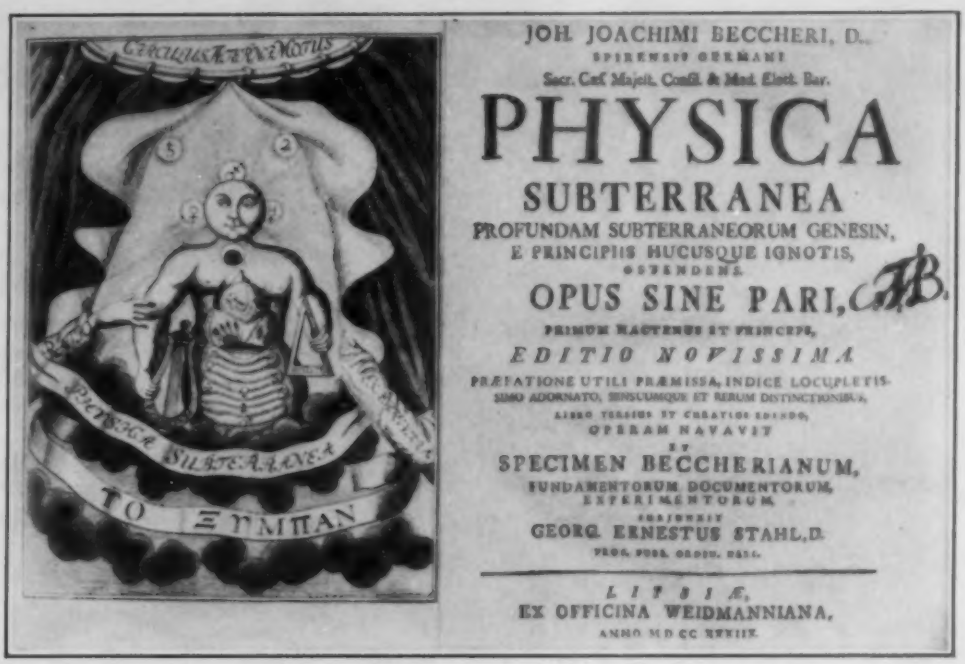
ENGRAVED TITLE-PAGE OF A LATIN EDITION (1669) OF THE FIRST SCIENTIFIC WORK BY ROBERT BOYLE, ENTITLED "THE SPRING AND WEIGHT OF THE AIR." "THE GENERALIZATION WHICH CARRIED BOYLE'S NAME TO POSTERITY, *i.e.*, THAT THE VOLUME OCCUPIED BY A GAS IS THE RECIPROCAL OF ITS PRESSURE, DID NOT APPEAR IN THE FIRST EDITION (1660), BUT WAS BROUGHT FORTH LATER (1662). . . "—J. F. FULTON, "A BIBLIOGRAPHY OF ROBERT BOYLE." ORIGINAL IN THE EDGAR FAHS SMITH MEMORIAL COLLECTION, UNIVERSITY OF PENNSYLVANIA.

A VIEW OF THE OFFICE OF FORMER PROVOST EDGAR FAHS SMITH (1854–1928) OF THE UNIVERSITY OF PENNSYLVANIA. THE COLLECTION IN THE HISTORY OF CHEMISTRY ASSEMBLED BY HIM IS NOW LOCATED THERE.

precious. To me it had little or no meaning, so I laid it carefully away. . . . In due course came an awakening, somewhat after this manner. I'd been discoursing on the oxy-hydrogen flame. I was well pleased with my presentation of it, when a lad not noted for an inquiring mind, asked who invented the oxy-hydrogen flame—how long has it been known—how did its discoverer happen upon it—was it of French origin or German? Quite a few questions from one untutored mind, you'll grant, and I acknowledge I could not answer any of them. What I said to the student I do not recall—but probably one of those camouflage answers even professors have been known to give—just to recover their breath, so to speak, that is to get time to look up the subject under discussion. You may rest assured I did look up the oxy-hydrogen flame, but nowhere did I discover anything about its origin. You may imagine that I was far from being happy—yes, very far. I ventured to consult several colleagues in a very cautious way. They gave me no aid. The questions couldn't be forgotten, when some good angel whispered to me—look over your old chemical books and pamphlets—that stuff you've been gathering and filing away with such solicitous care. At once I brought forth my old documents, and right there among them was my old purchase at ten cents. And there was the original account of the old compound blow-pipe by Robert Hare. Oh! it was a treasure, and I was able to tell my students a story about the oxy-hydrogen flame such as no text-book in their accessible library could give them.[1]

Fine bindings, first editions, the rare and the unusual appeal to many. These are represented in Dr. Smith's collection, but he assembled the material primarily for content of publication and for personalities. There are classics in chemistry as there are in literature. These were of great interest to him. He referred to chemistry as the "human science"—"It comes close to everyone's hearth and home. In every employment we feel its influence or want its aid."

[1] "Observations on Teaching the History of Chemistry," by Edgar F. Smith. *Jour. Chem. Education*, 1925.



PAGES FROM BECHER'S BOOK.

SYMBOLIC PLATE AND ENGRAVED TITLE-PAGE OF "PHYSICA SUBTERRANEA," THE MOST IMPORTANT WORK OF JOHANN JOACHIM BECHER, 1635–1682. HIS THEORY OF THE CONSTITUTION OF MATTER FORMED THE BASIS OF THE PHLOGISTON THEORY AS INTERPRETED AND EXTENDED BY STAHL AND HIS FOLLOWERS. ORIGINAL IN EDGAR FAHS SMITH MEMORIAL COLLECTION, UNIVERSITY OF PENNSYLVANIA.

The history of chemistry he regarded as the cultural side of the science. In learning to know his books, he said: "My early drill in the languages aided greatly; indeed, the dead languages lost their deadness." He urged others to collect like treasures and "not to be deterred from so doing because a friend in a thoughtless moment, has termed him a 'crank' or a 'mere collector!' As one grows older in the work he smilingly accepts these designations of affection."

As the collection exists to-day it bears the imprint of Dr. Smith's personality. Old engravings, aquatints, lithographs and photographs of chemists of all nationalities; autograph letters and manuscripts of the great ones—Mendelejeff, Boerhaave, Berzelius, Faraday, Pasteur, Madame Curie; books, alchemical and chemical, all gathered with loving care from the far corners of the earth, that the memory of those who have contributed to the sum total of the world's happiness and development might be honored.

This special collection is an unique and outstanding monument in the history of chemistry. When Dr. Smith passed away in 1928, it was presented to the University of Pennsylvania by his widow and endowed by her as The Edgar Fahs Smith Memorial Collection. It is used at the university to illustrate the teaching of the history of chemistry, and it is open to scholars everywhere who seek rare source material for scientific papers and other publications. Because

THOMAS COOPER, 1759–1840

ONE OF THE MOST INTERESTING AND STIMULATING CHARACTERS OF HIS PERIOD IN AMERICA. EDUCATED AT OXFORD UNIVERSITY, HE SETTLED IN THE UNITED STATES ABOUT 1795. PROFESSOR OF CHEMISTRY AT DICKINSON COLLEGE AND THE UNIVERSITY OF PENNSYLVANIA, PROFESSOR AND PRESIDENT AT THE UNIVERSITY OF SOUTH CAROLINA, HE WAS ALSO ACTIVE AS AN AUTHOR, JUDGE, PHYSICIAN AND POLITICAL ECONOMIST. HE WAS A FRIEND OF THOMAS JEFFERSON AND JOSEPH PRIESTLEY. A TURBULENT FIRE-BRAND, HE WAS IMPEACHED AS A JUDGE AND IMPRISONED AND FINED IN PHILADELPHIA FOR LIBEL OF PRESIDENT JOHN ADAMS. PHOTOGRAPH OF SILHOUETTE FROM THE WILLIAM H. BROWN PORTRAIT GALLERY, 1844.

of the close association of early chemistry to medicine and to physics, examples of the latter sciences are also present.

In this library modern critics might profitably peruse "A Description of New Philosophical Furnaces, or A New Art of Distilling," by Johann Rudolf Glauber, London, 1651. Oliver Cromwell wrote: "This Glauber is an errant knave. I doe bethink me he speaketh of wonders that cannot be accomplished." But nearly three hundred years later Ferguson in his "Bibliotheca Chemica" pronounced Glauber's work "one of the most remarkable books on chemistry of the seventeenth century." These kind words would have heartened Glauber, who was a sensitive soul and labored under fear of criticism, as is shown in the following abstract from his book addressed to all critics:

> To the Malitious. Whosoever thou art, O malitious carper, marke what I say. Do not despise things unknown, for there is no man in the earth can please all. . . . Truth shall remaine, when haters of truth shall perish. . . . Wherefore do not touch the innocent, that seek nothing but thy good; and shews the right way to get wealth and honour. If thou hast anything better communicate it; there is no body will hinder thee; if not bridle thy tongue, and do not carp at him that is through the blessing of God, eminent in the arts.

We handle reverently Elias Ashmole's "Theatrum Chemicum Britannicum," London, 1652. It is a compilation of verses upon alchemy and the alchemists by Chaucer, George Ripley, Thomas Norton and others—and the great Sir Isaac Newton paused to read what they have said. This volume contains the bookplate of Sir Isaac Newton, and is corrected and annotated in his hand. The name of Thomas Norton, author of the "Ordinall of Alchimy," contained herein is curiously revealed in the first word of the poem and the initial letters

AN OLD DRAWING TO SHOW EXHILARATING EFFECTS OF NITROUS OXIDE GAS. ILLUSTRATION FROM A THESIS PRESENTED TO THE MEDICAL SCHOOL OF THE UNIVERSITY OF PENNSYLVANIA IN 1808 BY WILLIAM P. C. BARTON, ENTITLED "A DISSERTATION ON THE CHYMICAL PROPERTIES AND EXHILARATING EFFECTS OF NITROUS OXIDE GAS, AND ITS APPLICATION TO PNEUMATIC MEDICINE." BARTON BECAME PROFESSOR OF BOTANY IN THE UNIVERSITY OF PENNSYLVANIA AND A SURGEON IN THE UNITED STATES NAVY.

of six following chapters, together with the first line of the second chapter:

> Tomais Norton of Briseto
> A parfet Master ye maie him call trowe.

"Elementa Chemia," by Johann Conrad Barchusen, 1718, contains beautiful symbolic plates portraying mysterious alchemical processes. In this we find marginalia of the poet, Samuel Taylor Coleridge, who is known to have had a deep interest in mysticism and the occult. On the fly-leaf he wrote:

> John Hartwell Bonsall Williams—
> Lord help you, Sir! We have not room for half of you.

Philosophies other than chemical may be found in many of the old volumes. Oswald Croll's "Bazilica Chymica," first published at Frankfort in 1608, passed through eighteen editions in fifty years, and the printed marginal notes to his "Doctrine of Signatures" contained in a translation attract us:

> The vertue of many things are unknown to us, only through our own negligence of experimenting them.
>
> Many things by most learned men might be obtained, if through false Ambition they do not persuade themselves to be sufficiently learned already.

And the following initiates us, perhaps, into the secret of the luxurious growth of hair of many of the ancients:

> The Haires of a Man, if distill'd, a juyce comes forth, which used by annonyting is profitable in prolonging the Haires of the Head.

In "The Art of Distillation," by John French, London, 1653, with seventeenth century marginalia, we read an ingenious defence of alchemy:

> Did not Artefius by the help of its medicine live 1000 yeares? Did not Flammell build fourteen hospitals in Paris besides as many in Boleigne, besides churches, chappels with large revenues to them all? Did not Bacon do many miracles? and Paracelsus many miraculous cures?

And among the strange secrets revealed is one on "Luminous water to give light by night, made by distilling glow-worms' tails or herrings skins."

"De Veritate et Antiqvitate Artis Chemiae," by Robert Vallensis, Paris, 1561, is of especial interest because it is the first attempt to present a history of chemistry. The copy noted is the first edition in original covers—48 unnumbered leaves, printed in italic type by Frederick Morrell, a pupil of Aldus Manutius. We know there is a copy in the British Museum—there may be another in the United States—and we handle it with reverence that such a tiny thing should have survived and grown old so beautifully through the passing centuries.

And so we come to the apology which Dr. Smith felt called upon to make to the guild of chemists for wandering from the path of pure science into the byways of collecting:

> There are those who think and, it may be, declare that chemists ought not to dream, yet I frankly confess as I have sat gazing at a near-by old-fashioned book case, that I have dreamed —because, the higher shelves carry musty volumes which in their day did—
>
> "Fill the world with dread,
> Were much admired,
> And but little read,—"
>
> for they are old chemistries—that's all! which have gradually grown in number. Tho' seared their leaves, crude their bindings, often dreadfully worn and decayed—they recall as do old, old letters of love and story—that
>
> "Through those manifold, twinkling, sparkling pages something of the past beckons us, whispers us, delights us, and above all in the magic phrase of Keats, teases us out of thought, as doth eternity."[2]

[2] "Old Chemistries," by Edgar F. Smith. McGraw-Hill Book Company, 1927.

THE GANGES DELTA

By Dr. A. S. PEARSE

PROFESSOR OF ZOOLOGY, DUKE UNIVERSITY

For centuries the Ganges River has been depositing mud at its mouth. From the southern border of the Himalayas and Central India the turbid waters of its tributaries carry silt past Delhi, Agra, Benares and other famous cities to deposit in its great delta, which thus continually encroaches on the Bay of Bengal. As long ago as 1840 Smith made borings to a depth of 481 feet and found alluvial deposits. From May to November it really rains south of the Himalayas. Pelseneer (1906) pointed out that the heavy rains at the head of the Bay of Bengal dilute the ocean so that marine animals there have become adapted somewhat to fresh water. But Annandale (1922), after studying the animals in the Ganges Delta for many years, was astonished that so few species were able actually to attain from the sea to the river. There are, however, a few typically marine animals which have invaded the river itself—horseshoe crabs (Limulus) are seen at Calcutta; there is a porpoise which lives in the Ganges and never goes to sea.

For many years the great Ganges Delta has allured me. What an opportunity to observe estuarine animals! In 1930 I got my chance. In Calcutta the staff of the Indian Museum was most helpful. The director, Colonel Seymour-Sewell, Sundar Lal Hora, Hem Singh Pruthi, B. G. Chopra and others proved to be most competent and agreeable gentlemen. We ate lunch together at Firpo's Restaurant. Afternoons at tea in the museum building we talked of everything from Ghandi to crabs. A rich ornithologist at the museum, Satya Charn Law, took me to his home and to his magnificent country estate where deer and pheasants lived beneath slender palms and beautiful shrubs. I was established in the Grand Hotel and soon learned to enter between the stolid Brahmin bull and the little handless beggar girl without trepidation. The Museum and the Bengal Natural History Society next door are

THROWING A CAST NET

A BACKWARD SWING, A SKILFUL WHIRL, AND THE NET FALLS OVER UNWARY FISHES IN THE RIVER BELOW.

SCENES FROM DAILY LIFE IN INDIA

Top: left, A GENTLEMAN GETTING SHAVED ON THE STREETS OF CALCUTTA; *right,* CHILDREN PLAYING JACKSTONES. *Middle: left,* A LEPER WITH TURTLES; THE TERMINAL PHALANGES ON EVERY FINGER AND TOE HAVE SLOUGHED OFF. *Center:* A GIRL BESIDE THE ROAD TO PORT CANNING; *right,* A COUNTRY SQUIRE ON A DIKE ALONG THE GANGES. *Bottom: left,* INDIAN CROWS WITH A ZEBU AND A COW; *right,* SPINNING AND WEAVING CAST NETS.

great treasure houses, not only of specimens, but of fine and antique books. Perhaps most wonderful of all are the rows of cases of Kashmir shawls, fine rugs and tapestries.

After several conferences it was decided that Port Canning would be the best place to study the Delta. The museum collector, R. Hodgart; a messenger, Ganoor; a cook, Iqussain, and an assistant cook accompanied me. Along the road to Port Canning the farmers were plowing their rice fields, knee deep in water behind patient zebus. At each station a boy walked, shouting, beside the train. When signalled he deftly whacked off the top of a cocoanut and presented it to a thirsty traveler, for an anna. There was no other drink to be had.

TWO GIRLS BESIDE A MUD WALL

WHICH ENCLOSES A MUDDY GARDEN BESIDE A MUD HOUSE.

At Port Canning the caste system made it necessary for us to hire a local sweeper to come each day, for there are some things which it is disgraceful to do, and sweeping appears to be considered about the worst of these. The collector was most capable; Ganoor cheerfully waded about in mud to collect animals; Iqussain seemed to spend most of his few waking hours smoking a water pipe made from a cocoanut and a bamboo tube, but furnished most satisfactory food. The Public Works Department gave me two rooms on the second story of a government bungalow. From these the dike along the Malta River (one of the many mouths of the Ganges) could be seen for more than a mile. All the wit and beauty of the region used the flat top of the dike as a highway and there were many curious things to see.

As soon as the sun was up in the morning the landscape was dotted over with squatting citizens, who after relief resorted to the nearest body of water to wash by hand their soiled posterior ends. Immediately after them to the same waters came other men to wash their teeth, housewives to dip up water for their morning meal, and cleanly persons who desired to drive in their sheep or cattle for a morning bath. Thus the Hindoos successfully maintain disease

LOW CASTE GIRLS

WHO MUST SPEND THEIR LIVES SWEEPING, HERDING PIGS, AND IN OTHER DEGRADING OCCUPATIONS.

HEM SINGH PRUTHI AND THE WRITER

IN THE COURTYARD OF THE INDIAN MUSEUM IN CALCUTTA.

and high mortality. Except when forced by arbitrarily imposed order from a British officer, sanitation is unknown in India. During the early day a continual procession of people and other animals passed along the dike: graceful women with shining brass pots on their heads; sturdy fishermen spinning or weaving nets as they walked; slow feeble lepers; plodding sufferers from elephantiasis with gigantic limbs or genitalia; laughing, more or less naked children; goats, sheep, pigs and cattle. During the heat of midday there was little traffic. At night it became active again. I then sat alone on my portico, the only white man for many miles, and felt lonesome. There was no light for reading or writing. Great fruit bats two feet long flitted past like evil spirits to engage in their nocturnal robberies. And it rained, sometimes drizzled and sometimes poured, but always rained. I went to bed.

Along the side of the dike next to the river there was an interesting group of animals not only in the river itself but in rather definite zones through the twenty feet between low- and high-tide marks. Among the common inhabitants of the water was the fish, *Aoria gulio* Hamilton-Buchanan, three air-breathing fishes which will smother if kept under water—*Ophicephalus striatus* Bloch, *O. gachna* H.-B., *Saccobranchus fossilis* H.-B.—and a strictly aquatic goby, *Glossogobius giurus* H.-B. In the mud near low-tide mark lived two slender little fishes (*Apocryptes lanceolatus* Bloch and Schneider; *Tanaeoides rubicundus* H.-B.) in burrows. They rested with heads at the mouths of their burrows and snapped up small animals carried by passing currents. Above these beach-skipping gobies rambled about over the mud (*Periophthalmus* sp.). These active fishes have protruding eyes and see well in the air. They catch small animals, as worms and insects, in such a way that there is no doubt that they see

ON THE HOOGHLY RIVER
ONE OUTLET OF THE GANGES.

them well from a distance of several feet. The ventral fins of these gobies form an adhesive disk which enables them to climb up vertical surfaces.

Crabs, like the fishes, are arranged in zones along the dike. A hermit crab (*Clibanarius padavensis* de Man) wanders over the mud near the water, and a great swimming crab (*Scylla serrata* Forsk., de Haan) forages. The gill chambers of the latter are commonly infested with little commensal barnacles. On the mud flats two crabs, *Dotillopsis brevitarsus* (de Mann) and *Metaplax dentipes* (Heller), scurry about or bury themselves in the mud. Near high-tide mark there is an active hermit crab, *Uca manni* Rathbun, which, like the beach-skipping gobies, feeds only out of water, but never builds burrows far from the river, for it must carry water in its gill chamber. However, another crab, *Sesarma taeniolatum* White, lives continually above high-tide mark under rubbish and breathes air. Two crabs, *Parathelphusa spinigera* (W.-M.) and *Varuna litterata* (Fabricius), live in the river and in neighboring fresh waters, often at some distance from the river itself. The former is an estuarine species and the latter is a proper fresh-water crab which has no close marine relatives.

In any estuary there is a struggle among animals which are trying to spread to new habitats; an eternal struggle which has been going on almost since life and habitats began. With an open highway and a graded series of salinities it seems strange that so few animals have been able to leave the ocean and enter rivers; or move from rivers to become established in the ocean. Of all the fishes known, less than twenty-five species migrate freely from sea to river. Ichthyologists and paleontologists maintain that bony fishes originated in fresh water. All marine teleosts have therefore become adjusted to life in the ocean, but it has taken a long time. A few insects and mites have left the land to live

WHEN A HINDOO PLOWS HIS RICE FIELDS
HE WADES IN WATER UP TO HIS KNEES.

THE PARESNAT TEMPLE IN CALCUTTA

in the ocean. Annandale (1922) believed that of the some hundreds of animals listed by naturalists from the Ganges River only about ten had clearly come from the ocean.

Along the shores of the Malta River each animal has spread into its appropriate niche and seldom is able to go farther. Some types are not able to leave the sea because they lose salt from their blood. Their external membranes can not maintain the internal fluids in such concentration as to permit body cells to live. Others are turned back by enemies or competitors. Some animals from estuaries migrate into fresh water each year but are unable to breed there. It is more difficult for an aquatic animal to breathe in fresh- than in salt-water. The salts in the ocean actually make respiration easier. Burrowing animals in tidal areas have protection underground from desiccation when the tide falls, but only rarely in the past have they been able to attain life on land.

So the struggle goes on in the Ganges Delta. On the fertile land people struggle against exploitation by propagandists who tell them that Ghandi will give them free food, clothes and idle ease when India is independent; against terrible age-old traditions of caste, dogma and ignorance; against cholera, plague, elephantiasis and other diseases; struggle to live and increase. In the hydra-head of the river animals struggle to hold their own and are eternally striving to spread into new habitats where they may perhaps find peace, quiet and food. But usually species are put rather definitely in their places by nature. Each animal comes into existence with a definite range of tolerations to variations in environment. Where millions try to attain new things, one may succeed.

CEREALS AND CIVILIZATION

By MORRIS HALPERIN

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The Nomadic Life of Early Man

Primitive man lived by wandering on grasslands as a hunter of the grass-eating animals which constituted probably his sole food-supply.

The hunting stage of early man's life was followed by that of grazing, in which man domesticated the horse, ox, sheep, goat, pig and dog and made a somewhat settled abode for himself and for his animals on one or another favorable piece of grass-land. However, occasionally there would be a year of great drought in which the grass "crop" was a total failure, with the result that the animals had no feed and would perish. The perishing of the grass-eating animals reduced man's food and compelled him to wander with his surviving cattle in search of pasture. That type of life was very uncertain—people did not know when a drought would dispossess them from their abode and not always would there be another abode to go to.

Grass Cultivation: These successive stages of hunting and grazing then "evolved" into the third scene of the agricultural melodrama, namely, the cultivation of the cereal grasses—those grasses which man found to be good food for himself. The grain of one harvest could be *stored* until the sowing time of the next season or even for a few seasons. This carry-over of grain tended to offset the ravages of drought. The result was that man could stay in one place more or less permanently and thus obtain a portion or even all of his food supply direct from the cereals, or else could carry the grain with him anywhere he desired and sow it there.

It was thus that cereal-raising, the earliest form of agriculture, was spread to other localities which trial-and-error methods showed to be suitable environmentally for the cultivation of the various cereals. Human life changed from that of wandering to that of settling-down. Man changed from a mere food-gatherer to a food-producer, and from the purely meat diet of the hunting stage to the mixed meat-and-grain diet in the era of agricultural cultivation with all that that implied of tillage, ecology and even plant-breeding.

Cereals, Leisure and Civilization

The tremendous importance of this change was that in every place where cereal-cultivation became established civilization set in; and, stated conversely, history has no record of any true civilization which developed without cereal-production as its basis.

When people wander, as do the modern Baktyari and other tribes, it is a practical impossibility to "settle down." The essential point in this whole regard is that the insurance of a food-supply, which the raising of cereals, entirely or nearly so, brought about, provided leisure. That is the keynote for any mental or spiritual progress that has ever occurred in any people. It is in this leisure of early man that we see the beginnings of art, of science, of language and literature, of social life, indeed of thinking itself. Moreover, cultivation of land permitted the conservation of the energy formerly spent in roaming; it led to a sense of ownership of land (with the consequent interest in improving it), and to the continuous development of metallic tools and appliances for so doing. In general, the cultivation of cereals made it both necessary and possible for man's civilization to begin and

to continue, as can be seen by a study of the history of man in all parts of the world, from prehistoric times down to the present.

INDIAN CORN IN AMERICAN CIVILIZATION

On the entire American continent, from Canada in the north to Patagonia in the south, the existence of the people was virtually synonymous with the cultivation of one cereal, *viz.*, maize or Indian corn.

Maize among the North American Indians

To the American Indians, maize was a miraculous gift from the gods. In one well-known version, Hiawatha yearned that his people might have a more sure source of food than was provided by hunting and fishing. The answer to his fervent prayer was Mondamin, whom Hiawatha overcame and buried and from whose grave emerged maize, the ever-dependable food for Hiawatha's people.

Nearly all the other Indian tribes had one or another myth regarding the origin of their great food, the maize plant. It was the American Indian, by his keen "field selection," who developed maize to its present rank of being the most highly specialized grass in existence.

In the Great Lakes region, the Indians lived largely on maize, but in addition they gathered wild rice (also called Indian rice) growing in wet "land" through which the squaws traveled in canoes, tied an armful of the plants together just below the heads, allowed the bundles to ripen, and returned later to "thresh" the grain by beating the tied heads over their canoes.

Amongst the Iroquois, the marriage contract was celebrated by a ritual in which the bride brought two maize cakes to her prospective mother-in-law.

The Mannharis had a harvest celebration in which the dancing women represented the ripe and swaying maize-plants; the men represented the reapers of the crop and the plowers of the field.

The Osage girls expressed their desire for marriage by giving their fiancé a piece of maize bread.

The Modern Hopi and Papago Indians

In their extreme isolation in northeastern Arizona, the modern Hopi Indians are still very primitive in their agricultural practices. The Hopi have very few tools and they practice little or nothing of modern farming in their cultivation of grain. When the maize is harvested, it becomes the property of the housewife, who has learned, through sad experience, that she must carefully store away enough maize to tide her family through at least the next year of possible drought. She watches diligently for weevils; when she spies any she calls in her woman neighbors, who together form an inspection squad, giving every ear of maize the "once over"; any weevils which are so unfortunate as to be detected and captured are ceremoniously removed and "humanely destroyed." The housewife prepares maize in an epicure's variety of ways. A special occasion is the ear-roasting outdoor picnic, at which the farmer and his family assemble with their friends and have a happy time feasting on ears of maize roasted in the fire.

The Papago Indians, who live on a reservation near Tucson, Arizona, are experts in dry-land farming. They raise maize and Sonora wheat from which they make their native breads. Some of them mix wood-ashes with their wheat seed before sowing; and when asked for the reason for adding the ashes, they merely say, "It is good!" The Papago threshes wheat by the ancient method of preparing a "floor" on which he lays the wheat. Then he adds his own method of driving several ponies over the wheat, a process "catalyzed,"

no doubt, by the abundant perspiration (and probably other exudates) from the body of the animals. When the appetizing threshing is over, the grain is winnowed by being thrown in the air. The surplus grain is stored in a granary made out of coarse grass.

The Ancient Mexicans

The civilization of the Aztecs (the partial ancestors of the modern Mexicans) was also based on maize. Several varieties of this cereal formed the chief part of the diet among the Aztecs. The maize grain was made into bread and pancakes and porridge. The Aztecs' chief beverage was made by fermenting the grain or stalk of maize.

After certain religious ceremonies, the girls crowned themselves with chaplets of maize. In their idol-worship feasts, a long cord ornamented with grains of dried maize strung on threads into the form of a wreath was placed around the esteemed idol. For periods of four years, penitent and austere priests lived on a daily ration of a small loaf of maize bread and a cup of "stolli," which was a sort of soup made also from maize. In periods of public calamity, the high priest of Mexico lived for one year on raw maize and water.

The Maize Civilization of the Mayas

Among the Mayans, in Mexico and in Central America, maize formed the basis of nearly every dish. Large balls of maize were preserved dry for several months and were eaten dry or, for a beverage, were broken up and mixed with water. The Mayas made "hot cakes" by compressing ground-up maize-grain and heating the exuding juice until it curdled.

All the Mayan religion was featured by maize. For instance, in their story of the creation of the earth, maize was the material from which the three "Creators" made four men who later, when asleep, gave rise to four women, thus beginning the Mayan race! In the elaborate ceremony which the Mayas practiced in baptizing their children, incense and a few grains of maize were the indispensable substances employed. They worshiped chiefly the maize god, the lord of the harvest fields, whom, however, from sad experience, they always depicted as being himself dependent upon the gods of rain and drought. At their religious sacrifices and New Year's ceremonies, maize cakes and maize loaves were very prominent. At a burial, a few grains of maize and some stone money were put into the mouth of the deceased (the maize kernels were apparently to be the corpse's means of subsistence until he reached the next world, and the money was intended for the purchase of provisions after he arrived there).

In the ordinary life of the Mayas, there was only one important activity which did not involve maize: The mothers used a stinging pepper to rub the bodies of their disobedient children to punish them. Except for this, the maize plant constituted the chief article in the existence and life of the Mayas.

It should be added, however, that the production of maize year after year on the same land is considered to be one of the causes for the downfall of the Mayan civilization. The failure to use other plants in a system of crop-rotation resulted in depleting the fertility of the soil and, eventually, probably led to the failure of agriculture and ultimately (in this particular case) brought about the death of the very civilization to which it gave birth.

Among the Caribbeans, the young man brought the prospective father-in-law some maize bread with which to celebrate the marriage.

The physical existence and the social and religious life of the Pueblos, Guatemalans, Incas and Peruvians were also centered upon maize.

From diaries and other records it is learned that the early settlers of the present United States brought seed of rye, wheat, oats and barley with them from Europe and planted these for crops as early as 1625—crops which, by 1925, were amongst the most valuable products in the country.

Maize in South America

Along the Orinoco River, the Wapishana and other peoples grow rice, introduced probably from the East Indies, which they use in addition to the maize growing wild there. Throughout the Guianas, maize is the staple crop and the dietary mainstay. The Otomac Indians there grow a variety of maize which they call "two-months' maize" (mais de los mesas) because this variety requires only two months for its complete "life cycle" from sowing to harvesting and thus yields six crops a year.

The Makusi of the upper Cotinga make bread from a mixture of manihot and maize meal as well as pap made of pounded maize boiled with cut-up pumpkin. On the Curiebrong there is a product called "aknaikh," a mixture of maize and buck-yam pounded together with a mortar and pestle. These South American people make a fermented maize drink which is quite popular. Maize, ground with the vigor of a woman's arms, is made into loaves called "cayzu." These are allowed to stand from fifteen to twenty days when they become covered with mold, which is yellow on the elevated plains and green on the warm lands. Thereupon they are christened "subibzu," crushed to powder and mixed with a large quantity of hot water to which sugar is sometimes added. The product is strained and collected in large earthen jars, where it effervesces on the third day, the resulting beer being considered a healthful drink and a close competitor of the alcoholic products of cassava.

Outside of the Western hemisphere (North, Central and South America), wild maize is not found. In the Eastern hemisphere there are other grains, each of which has exerted a dominating influence in the initiation and the development of human life.

CEREALS IN AFRICA

The Great Egyptian Civilization

On the African continent we find one of the world's oldest civilizations, that of the Egyptians. Barley has been found in Egyptian pottery jars dating from 4000 B.C. Millet too was cultivated at that time.

Wheat has been found in the bricks of the Dashur pyramid, which was built before 3300 B.C. Wheat has also been found in the Nile Valley, in the oldest known graves in the world. Wheat chaff, being easily removed from the grain before the making of the bread, is not found in the stomachs of bodies from these earliest cemeteries; the chaff of barley and of millet, present in the bread, is, however, found in these graves. Sorghum has been grown in Egypt since primitive times, but no remains of it have been found in these tombs.

The Egyptians considered wheat a gift from Isis, the principal Egyptian goddess, who originated agriculture as well as the arts which accompanied agriculture and who symbolized fertility. In the Egyptian "Book of the Dead," King Osiris states: "I am Osiris. I live as Grain. I grow as Grain. I am Barley." In Egyptian literature there are poems which mention "barley, wheat, and fruit trees," probably indicating the order in which these were important. Apparently the Egyptians, although only mild imbibers, were held by others in contempt for their intemperance, for in one of the poems of Aeschylus a king of Agros assures the Danaids who had just come from Egypt that here they "will find a manly population and not

drinkers of barley wine." Rice is an ancient crop in Egypt, whence it came from India. The beginning of the "evolution" of the modern plough was the hoe used in Egypt in the growing of barley.

Cereal Astronomy and the Cereal Calendar

The Egyptians were the world's first astronomers. Their interest in astronomy was motivated entirely by the desire to watch the movements of the moon, in order to notice its effect on sowing and on the other steps in cereal-raising.

Closely associated with the interest which the Egyptians had in astronomy was their priceless contribution to civilization in the form of the calendar. In the nomadic life of primitive man, the day was for hunting and the night was for sleeping. But the settled abode which came with cereal cultivation made it very desirable to keep a record, largely on the basis of the moon's activities, as to when it had been found best to sow and irrigate and perhaps fertilize the growing grain. By doing the various steps in cereal production during certain "months" and on a certain number of days after the "new moon," the chances for success were improved greatly over haphazard agricultural activities.

The earliest dated event in history is the establishment, in 4241 B.C., of the Egyptian calendar of twelve months of thirty days each, plus five feast days. One month was called "Sprouting of the Grain" and others were called "Making and Watering Barley," "Ripe Grain," "Lady of the Granary" and "Grain Gods"—all these indicating markedly the agricultural necessity for, or desirability of, the calendar, an invention which passed by way of the Babylonians, Greeks and Romans to the modern peoples of the Christian era.

The Two Great Papyri

Very intimately associated with both astronomy and the calendar among the Egyptians was obviously mathematics. This great science too developed out of the necessity for calculations relating to cereal production.

The present scientific knowledge of Egyptian mathematics is contained in two papyri, the Rhind papyrus and the Golenishchev papyrus. In the Rhind papyrus, written about 1650 B.C., problems 41 to 46, inclusive, deal with the dimensions and volumes of cylindrical and parallelopipedal granaries, showing that the necessity of storing surplus or reserve grain for the next year of possible drought spurred on the Egyptians to find the shape of a granary which would hold the largest weight of grain for its volume. It is in these problems that is found the first Egyptian record, copied from the Golenishchev papyrus of about 1850 B.C., of the value for π of 3.1605, a very close approximation to its true value of 3.1416.

The Rhind problem 64 is one involving arithmetic progression:

> Distribute 10 hekat of barley among 10 men in such a way that the shares shall have a common difference of $\frac{1}{8}$ hekat. What is the share of each?

Problem 69 reads:

> $3\frac{1}{2}$ hekat of meal are made into 80 loaves of bread. Let me know the amount of meal in each loaf.

Problem 79 is very interesting:

> In each of 7 houses are 7 cats, each cat kills 7 mice, each mouse would have eaten 7 ears of spelt, each ear of spelt will produce 7 hekat of grain; how much grain is thereby saved?

In the Golenishchev papyrus, 10 out of the 25 problems pertain to the so-called pefsu or cooking-ratio of grains comparable to the modern "calories" of various foods.

Other African Cereals

Over large areas of Africa outside of Egypt, particularly in the Sudan, another cereal, sorghum, was the center of the people's existence. In Ethiopia, millet and barley were used for food and beverage. In tropical Africa, two other grains, teff and fundi, were the chief element in the diet. Amongst the Negroes in the Sahara, after the marriage contract has been closed, the man gives the bride's parents 60 liters of grain, a rich present in that district.

When a woman of the Nilotic Kavirondo tribes gives birth to a boy-baby, a stalk of Kafir sorghum is pulled out of the roof of the hut on the right side of the fireplace (looking from the hut outwards); if a girl, a stalk is pulled out from the left side.

The present names of sorghum varieties, such as kafir, milo, durra and feterita, used in the United States are African names.

CEREAL CIVILIZATION IN ASIA

On the vast Asiatic continent, we find most of the world's earliest civilizations, all of which were made both possible and necessary by the cultivation of one or another of the cereal grasses.

Rice in Chinese Civilization

If not the very earliest, then one of the earliest known civilizations arose in China, where it developed around another cereal, rice, one of the oldest plants cultivated by man.

The cultivation of rice gave the Chinese not only a sense of settled life and a relatively dependable food-supply, but brought them in contact with the soil and eventually with all nature. The ancient Chinamen learned that rice would grow only with irrigation, so that it was necessary to build levees, dykes, canals and elaborate terraces. These extensive mechanical and architectural changes could be made only by the whole community, so that social life and amicableness towards neighbors inevitably resulted. These changes also brought about *leisure*, which, in turn, provided opportunity for philosophical meditation and for literature. The same changes in the soil tied the Chinese still more to the land and made it precarious to engender wars with neighboring peoples in which they might be driven from their "homes" built up by long and expensive work. The strong sense of ownership which was produced by these improvements, and the normal surety of obtaining a cereal crop, doubtless favored an increase of population and eliminated aggressiveness on the part of the Chinese. There seems to be a definite agricultural basis for the personal characteristics traditionally associated with the Chinese.

Sorghum spread from Africa to China, where it became known as kaoliang, meaning "great millet," and it retains this name to-day even in American agriculture. Millet was cultivated since prehistoric times in China and spread from there westward to Europe, where it became known as Italian and German and Hungarian and Foxtail millets. In northern China, wheat was and is grown extensively.

In 2700 B.C., the Chinese Emperor, Chen Ming (Shennung), instituted the symbolic ceremony of sowing five useful plants each year. Those crops were rice, wheat, sorghum, millet and soybean, all of which, except the soybean, are cereal grasses. Rice, being the chief plant in the ceremony, used to be sown by the Emperor himself.

Cereals in Other Eastern Asiatic Civilizations

In Japan, rice has been grown since primitive times and still is the most important crop grown there. Millet too has been cultivated in Japan before the time of historical record.

In the Indian Archipelago, rice and

millet were cultivated since prehistoric times, the plants themselves bearing mute testimony of a long history of cultivation.

In Borneo the female Dayaks use a pot of rye to conceal an object of one kind or other whereby they indicate, in a modest tribal manner, the men whom they would like for their respective husbands.

Rice spread, probably from India, to the Malay Peninsula, where it became and has remained the dominant crop. In the Philippine Islands, too, rice became dominant, and it is cultivated there to this day on hillsides which are very skilfully terraced so as to hold rain and prevent runoff.

Rice and Barley among the Aryans

In India, rice was cultivated since nearly prehistoric times. Rice spread from India eastward and westward and southward to other parts of Asia. Sorghum and pearl millet spread into India from Africa. The cereal coracan is native to India.

The civilization of the Aryan cult in northern India of about 1500 B.C. was based chiefly on grains. Food consisted primarily of rice, which was husked by slave girls, and of barley, which was ground into flour and made into bread. A beverage called "sura" was made by distilling either barley or rice. To their gods, the Aryans offered up roasted barley and cooked rice; the person who cooked the rice, it was firmly believed, would not bear harm at any time but would be world-conquering and heaven-going! A baby when cutting its first teeth was fed on rice or barley. An "inherited" disease prevailing amongst the Aryans was dispelled by having some one wave "a straw of barley, tawny brown, with its silvery ears" close to the afflicted individual.

The Persians cultivated wheat as the chief constituent of their diet. Rice was entirely unknown in Persian (Iranian) antiquity; it is only since the time of the Arabs' conquest (7th century A.D.) that rice has been grown in Persia.

Babylonian Cereals

In the earliest Babylonian calendar, the names of six of the twelve months refer to the cultivation of grain and the names of two other months refer to the eating of grain, indicating the agricultural origin of the calendar. The tablet of Enkhegal, of about 3100 B.C., one of the oldest Babylonian inscriptions, states that land was paid for by bronze and by grain. By 1300 B.C., there was an appliance for plowing the land and sowing the seed of grain in one operation. Concerning Babylonia, the historian Herodotus, the "father of history," wrote in 450 B.C.: "The soil is peculiarly adapted to grain; no wine, olive, fig or other fruit trees are grown; only barley, wheat, and millet are grown."

The king of Iberia, in his palace, had golden and silver vessels filled with barley juice for use as a refreshment.

The ancient Armenians used millet for food and for drink.

The Syrians cultivated largely rice, which spread to Syria from India.

Cereals in the Holy Land

Another important Asiatic civilization was that of the Hebrews, concerning whom we learn a great deal from the Bible.

Joseph, in his first dream, saw his brothers' sheaves of grain (probably barley) in the field, bowing to his sheaves (Gen. 37: 7).

Pharaoh's second dream pertained to "seven ears of corn (doubtless barley) upon one stalk, rank and good" and "seven thin ears . . . blasted with the east wind" (Gen. 41: 5–7). The famine which soon followed was a dearth of grain; only in Egypt, by Joseph's advice, was the grain stored in huge quantities.

At the time of the plague of hail upon the land of Egypt, "the flax and the barley were smitten; for the barley was in the ear, and the flax was bolled. But the wheat and the rye were not smitten; for they were not grown up" (Ex. 9: 31, 32), indicating the Hebrews' knowledge of the relative order of maturity that pertains, in general, for these cereals in most other parts of the world to this day.

Moses, when leading the Israelites into the promised land, told them the rewards of obedience: "He (God) will give you the rain of your land in due season, the first rain and the latter rain, that you may gather in your grain and your wine and your oil" (Deut. 11: 14), the grain being mentioned first doubtless because of its eminence.

Wheat and barley are mentioned as indispensable parts of many of the offerings and sacrifices mentioned in the Old Testament.

Naomi, the Jewess, and Ruth the Moabitess, her daughter-in-law, "came to Bethlehem in the beginning of barley harvest." When Ruth gleaned in the harvest-field, she followed her mother-in-law's advice in that she "kept fast by the maidens of Boaz to glean unto the end of barley harvest and of wheat harvest." After the harvest, Naomi spoke to Ruth concerning "Boaz of our kindred with whose maidens thou wast. Behold he winnoweth barley to-night in the threshing floor." It was there that Ruth appeared to Boaz "after he went to lie down at the edge of the heap of grain" of which, before morning "he measured six measures of barley and laid it on her, and she went into the city."

When King Solomon needed lumber for the house which he "determined to build for the name of the Lord and an house for his kingdom," he wrote to Huram, king of Tyre, saying:

"And, behold, I will give to my servants, the hewers who cut timber, twenty thousand measures of beaten wheat, and twenty thousand measures of barley, and twenty thousand baths (about one hundred and eighty thousand gallons) of wine and twenty thousand baths of oil" (2 Chron. 2: 10). Here again the grains are given first rank; and, be it noted incidentally, the wheat was "beaten" while the barley, with its adherent chaff, was not!

The prophet Joel, when speaking to the Jews of their poverty, says: "Be ye ashamed, O ye husbandmen, weep, O ye vine-dressers, for the wheat and for the barley; because the harvest of the field is perished" (1: 11). Apparently even the grape-growers depended upon grain for their mainstay, for they were exhorted to lament for the failure, not of the vintage but of the grain-crop!

The good and patient Job, in his grief, asserted that if he had ever taken aught that was not his, "Let thistles grow instead of wheat and cockle instead of barley" (31: 40).

In "The Book of Jubilees," a Judaistic work of the second century B.C., it is stated that Abraham made an implement for sowing and plowing in one operation, in order to "keep the grain-seeds out of reach of the ravens sent by Satan to devour men's crops."

In the impending shipwreck during Paul's journey to the assembly at Rome, it was found necessary, in order to lighten the ship, to cast out the cargo of wheat into the sea (Acts 27: 38).

Rice is mentioned in the Hebrew Talmud, although not in the Scriptures.

It was in The Holy Land, on Mount Hermon, in 1906, that Aaron Aaronshon discovered a wild emmer-wheat, which is presumed to be the "ancestor" of cultivated wheat.

CEREALS IN EUROPE

The dwellers in the Swiss lake-villages of the Stone Age, about 2000 B.C., cultivated barley, wheat and millet.

Barley, wheat and millet were grown at the same time (about 2000 B.C.) in northern Italy. Millet has also been found in the remains of the lake-dwellers of Varene. The Arabs introduced rice culture into Italy and elsewhere in Europe, when they invaded that continent in the 7th century A.D. Probably about a thousand years later, maize was introduced from America to Italy, where it became established and has remained to this day the basis of a porridge which forms the usual dish of the peasants.

The lake-dwellers of Lombardy cultivated wheat. In what is now Hungary wheat was cultivated during the Stone Age. In Thrace (ancient Hungary), barley and millet were used for bread and beer. Barley has been found in the remains of the lake-dwellers of the Bronze age at Savoy.

When the Macedonians invaded Asia, they became familiar with rice, barley, wheat and millet, all of which they introduced into Greece. They were so fond of the cereals that they considered even oats in their grain-fields as a weed!

The Wallachians used maize, which they imported from America, to make "mamaliga," a dish still used by their modern descendants, the Roumanians.

In Germany, maize is called "walschkorn." A millet is also commonly used in Germany to make a mush called "brei," and in German little readers for children, there is a story of the "breipot" (the pot of millet mush) which floated down the Rhine.

In Holland, the Friesians have an old saying,

> As long as the breipot
> Yields ought to the spoon,
> Occasion for sorrow
> Will not be so soon.

The Lithuanians, Celts and Gauls also used millet, at least a sort of beer made from it. The Numantians (in what is now Spain) ate wheat and other grains and drank beverages made from these cereals. In Illyria, barley and millet were used for bread and for beer.

Russia is the home of rye. A Russian proverb says: "Bread ours, mother ours." The Ukraine region of Russia is the region from which came the earliest "hard-winter wheats," now grown extensively in improved varieties in the Kansas wheat belt.

The Great Finnish Epic

Barley has been immortalized in the Kalevala, the grand pagan epic-poem of Finland. In the very Proem (Prologue), the writer says (in J. M. Crawford's English translation):

> Let me sing an old-time legend,
> That shall echo forth the praises
> Of the beer that I have tasted,
> Of the sparking beer of barley.

Rune (chapter) II, entitled "Wainamoinen's Sowing," tells how

> Wainamoinen, wise and ancient
> Brings his magic grains of barley,
> Brings he forth his seven seed-grains, . . .
>
> Thence to sow his seeds he hastens,
> Hastes the barley-grains to scatter, . . .
>
> On the morning of the eighth day,
> Wainamoinen, wise and ancient,
> Went to view his crop of barley,
> How his plowing, how his sowing,
> How his labor were resulting;
> Found his crop of barley growing,
> Found the blades were triple-knotted,
> And the ears he found six-sided.

Rune XI, "Lemminkainen's Lament," tells how the Sahri maiden would not go to Ehstland because she would

> Hunger there and feel starvation;
> Wood is absent, fuel wanting,
> Neither water, wheat nor barley,
> Even rye is not abundant!

Rune XX discusses "The Brewing of Beer."

> Beer arises from the barley,
> Comes from barley, hops, and water,
> And the fire gives no assistance.

Then follows a great tribute to their wonderful beverage:

> Great indeed the reputation
> Of the ancient beer of Kalew,
> Said to make the feeble hardy,
> Famed to dry the tears of women,
> Famed to cheer the broken-hearted,
> Make the aged young and supple,
> Make the timid brave and mighty,
> Make the brave men ever braver,
> Fill the heart with joy and gladness,
> Fill the mind with wisdom-sayings,
> Fill the tongue with ancient legends,
> Only make the fool more foolish.

Cereals in Roman History

In Roman history, cereals played an important part in the agriculture and in the life of the people.

Columella gives calculations showing the amounts of grain to be sown upon areas of certain size. He gives other calculations showing the labor requirements for the various operations in producing wheat—an interesting forerunner of an important factor in modern farm-accounting. Columella mentions a millet which, with milk, forms a kind of porridge "not to be despised," and states that barley mixed with wheat makes good bread. In his time the Romans used to add chalk to their flour, in order to enhance its whiteness. Columella reports that animals thrive better on barley than on wheat. An inebriating beverage named Zythum, evidently a beer of some kind, known to be made from barley, is also mentioned by Columella.

Pliny describes the cultivation for human food of wheat, rye, oats, sorghums and millets. He gives directions for the preparation of Polenta, a porridge made from barley, which, being a very strengthening food, was fed to the Roman gladiators who were therefore called *hordeari* (from *hordeum*, the Latin word for barley).

The first reapers in Rome were invented in connection with the harvesting of grain—a reaping hook which consisted of a large and hollow frame armed with teeth and supported on two wheels, and driven through the grain so that the heads tore off and fell into the frame.

Varro noted that barley is better than wheat on dry land, and that the reverse applies on wet land—a difference which is still generally true.

In the feeding and fattening of birds, which was a very important dish with the ancient Romans, the birds' food was barley meal mixed with water, given sparingly at first and increased gradually, and, in some cases, a little wine added.

Horatius at the Bridge

Lord Macaulay's lay entitled "Horatius" relates how

> LVII
>
> Alone stood brave Horatius,
> But constant still in mind;
> Thrice thirty thousand foes before,
> And the broad flood behind.

For the grand and heroic stand which Horatius made, his reward was that

> LXV
>
> They gave him of the corn-land,
> That was of public right,
> As much as two young oxen
> Could plow from morn till night;
> And they made a molten image,
> And set it up on high,
> And there it stands unto this day
> To witness if I lie.

The Romans used grain to honor not only their heroes but also their gods. In fact, they had a goddess, Ceres, in whose honor were held grain festivals called Cerealia, whence our English word "cereal," the subject of this article.

SCIENCE SERVICE RADIO TALKS

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AMERICA'S EARLIEST MAN

By CHARLES AMSDEN

SECRETARY OF THE SOUTHWEST MUSEUM, LOS ANGELES, CALIFORNIA

We read of people flying across the Pacific Ocean, yet I can't remember any one walking across it. If I had to choose, I'd seriously consider walking, because the distance is only about fifty miles. You go up to the northwest tip of Alaska and there, fifty miles away across shallow Bering Strait, is the eastern tip of Siberia. In summer you'd probably find Eskimo paddling back and forth in their skin boats, while in winter the strait is often choked with ice, which you could scramble over dry-shod. This is the road by which many plants and animals got from the Old World into the New. So we shouldn't think of the two hemispheres as separated by vast oceans, but rather as joined firmly together beneath that little strip of ocean called Bering Strait, with plants and animals and men going back and forth since long ages past. Yes, men too; they follow the animals, just as the Indians followed the buffalo herds up and down the Great Plains.

Now you think I'm launched on one of those scientific pipe dreams of the Sunday supplement, don't you? Well, let me sketch a bit of the evidence so you can decide the matter for yourself. Plants and animals have ancestors, earlier and simpler forms of which they are the remote descendants. Often these ancestral forms are miraculously preserved: ferns in coal, fishes in limestone, elephants in frozen bogs, are familiar instances. So we can trace the family tree of many plants and animals, and we know that some are natives of America, others of Asia, a long time back.

The human animal has a long ancestry, too, which can be traced down the corridors of time like the others. You've heard the names Java Man, Heidelberg, Neanderthal and various others. Each is an ancestral form, an actual specimen of the human race at a certain point of its long evolution from the family of the great apes down to that of modern man. Some of them are hardly more than apes; others are little less than modern men. Where were these troublesome old gentlemen found; in America? No, not a single one of them. All are from the Old World. Only the modern types have been found over here. None of the great apes ever lived in America. So what must we conclude? Answer it for yourself.

That's going a long way back for our evidence; suppose we look for ancestors less remote. Well, there are only three great races or physical divisions of humanity in the whole world to-day, as every one agrees. They're the Caucasian, the Negroid and the Mongoloid, or white, black and brown. Asia is the home of the Mongoloids, so if the American Indian came from Asia across Bering Strait he should be one of that group. Sure enough, he is. He has in some degree every outstanding characteristic of that race. I'll mention only a few that we can all appreciate: complexion, shape of face, slanting eyes, color and texture of hair. Most convincing of all is a curious peculiarity of the upper front teeth. In 85 per cent. of the Mongoloids these teeth have incurving edges, shaping them like a shovel. The Indians have them, too.

So we've made some progress in our

hunt for America's earliest man. He must have come from the Old World because there's no sign of his having developed over here. And he must have come across Bering Strait because he couldn't reasonably have got here any other way. Now, to find our earliest man we must face a very troublesome problem—the question of time. Man has been measuring and recording the passage of time for about six thousand years. We'll have to get back farther than that, so we'll adopt one of nature's measurements as worked out by geologists. It's a tremendous climatic cycle known as the Ice Age. You've probably read that there are coal deposits within the Arctic Circle, which means that the arctic regions once had a climate warm enough to grow the plants that make the coal. At the other extreme of climate are the glacial deposits which prove that our Great Lakes region once lay under an ice sheet several miles thick in spots. Four times a great climatic change caused the formation of ice sheets over northern Europe and North America alike. They're ancestral forms, too; their descendants still live in the remote north, and Greenland is still covered. Three times in between these cold spells were warm spells, when plant and animal life changed completely, for the Ice Age was several hundred thousand years long.

There's our time cycle: four cold periods and three warm ones. It's important to human history because the oldest known remains of man in the Old World are found in earth layers or geologic deposits of the early Ice Age. And we can date the later remains by their position in the deposits of the succeeding periods. In short, the Ice Age is the great calendar of human history. Without it we could never hope to date America's earliest man.

By the time the last of the four great ice waves had started melting away, the human race was surprisingly well advanced. Instead of looking like hairy apes, its members had grown to resemble the men and women of to-day. They were using their brains and their hands to good purpose, making useful tools of bone, wood and imperishable stone. The changing forms of these tools give us a little calendar within the greater one of the climatic cycle, for they were being changed and improved constantly. In terms of our little calendar, the American Indian lives in the New Stone Age. That is, he knows how to make polished or smooth stone tools, as well as the earlier chipped or flaked tools. The New Stone Age began in Europe some ten thousand years ago, which suggests that the first Indians reached America some time during that period, after the last great glaciers had died away. If they had come much earlier, the argument runs, we should find their remains submerged in the glacial deposits of the last ice wave, or buried with the extinct animals of that period. With these remains should be stone tools of Old Stone Age type. All of which is good sound reasoning, because that's just the way it worked out in the Old World, in hundreds of instances.

In the past few years this view has been challenged by a whole series of discoveries. A human skull, not of the most modern type, was found under ten feet of glacial silt in Minnesota, near the southern edge of the last glacial wave. At several places in the Great Plains region, flint implements were found among bones of a species of buffalo that lived during the Ice Age. One of these finds was of eighteen such implements and thirty to forty bison, all of which lay buried under thirteen feet of a peculiar kind of soil called loess, which was blowing around the country when the glaciers were not so far away. In other instances similar implements lay among bones of the mammoth, an elephant now extinct. In Nevada a camp fire was found in an ancient dry cave below a solid layer of the dung of another extinct animal that

flourished in the late Ice Age, the ground sloth Nothrotherium. A cave in New Mexico yielded a flint implement with the bones of a musk ox, an animal built for a much colder climate than that of New Mexico to-day.

The implements in these finds were much like a type popular in Europe in very early New Stone Age times, perhaps ten thousand years ago. But recently, in the southern California desert, archeologists have found hundreds of camping places, with thousands of stone implements, most of which bear a strong resemblance to the European types of the late Old Stone Age, say 15 thousand years ago. These camps line the banks of three streams that no longer exist, their dry channels choked with drift sand. In one instance they cover the terrace or former beach line of a lake now dry, and this terrace stands forty feet above the present dusty bed. Native American camels and horses lived along these streams. We find their fossil bones strewn around the camps in thousands of fragments. When was the bleak California desert such a well-watered spot? Apparently not since the glaciers melted, the geologist answers, and by their melting created a humid climate.

So we have a growing body of new evidence to foster the search for America's earliest man. Apparently he saw something of the last great glaciers and the extinct animals that lived along their southern borders. The many dry lakes of the great inland basin, from Oregon to Arizona, were truly lakes to him. To clinch the argument, he hunted the same general group of late Ice Age animals, with the same general type of weapon, that were found in the Old World when the modern phase of the great climatic cycle was still young. And when was that? Here's our best answer to date.

A glacier melts fast in summer, slowly or not at all in winter. Every year it lays down a broad sheet of muddy water in one of the lakes that fringe its base. The mud settles in a thin film, and next year the process is repeated. These mud layers are visible to-day in many parts of Europe and America. Counting them, year by year, geologists have calculated that the last glaciers started their melting something like 20 thousand years ago. So we can estimate the age of America's earliest man as somewhere near that figure.

I must confess that this conclusion is not entirely satisfactory. It doesn't explain why nearly all our finds of early man in America are in the region south of the glaciated areas, which suggests that Canada and northern United States were still under the ice. But in that event, wouldn't Siberia and Alaska have been ice-bound, preventing migration? Well, not necessarily. Warm ocean currents may have freed the coastal belt of its ice mantle long before the interior was cleared. That's precisely what the Gulf Stream and the Japan Current are doing for northern latitudes to-day. Generally speaking, the sea is warmer than the land, and this would be the logical place for the glaciers to start their melting.

That's conjecture; in fact, much of what I've said and of what others say on this subject is conjecture. But here are a few facts as plain as the nose on your face. Man was in America when most of the big game animals were of the Ice Age group, not of the modern group we know to-day. He was here when the climate was far cooler and more humid than it is to-day. He made weapons that resemble most closely the types of the late Old Stone Age and the early New Stone Age in Europe. He apparently avoided the whole glaciated area of North America, for his remains are never found well within it.

Now the most conservative conclusion we can possibly draw from these facts is this. Man was in America at a time when its climatic and biotic conditions were still under the spell of the last great surge of the ice wave. Whether he came

during the long twilight of the Ice Age or earlier is an open question. Certainly he could not have come much later.

In other words, we've accumulated enough evidence to give us a fairly clear minimum age for man in America. But don't let anybody tell you we've necessarily reached as far back as the maximum. Most of our knowledge of man in the Old World comes from one country, France. France is smaller than the single state of Texas. If ever a tail wagged a dog, here's an instance. Centuries must pass before we'll know America as thoroughly as we know France. And what we learn may change the picture completely. We've taken just a few short steps on a long and difficult trail.

LIGHTNING

By Professor B. F. J. SCHONLAND
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I AM to speak to-day about some of our recent knowledge concerning the nature of the largest and most powerful electrical machines which exist on our earth —the natural machines we call thunderstorms. That the thunder-storm is an electrical machine was guessed three hundred years ago by the first workers on electricity. It was, however, that great American, Benjamin Franklin, who first showed in 1752 by direct experiment that thunder-clouds are electrically charged.

In spite of the great growth of electrical science and the frequent occurrence of thunder-storms, little more was learned about the workings of these natural electrical machines until comparatively recently. Within the last fifteen years, however, investigators in different parts of the world have succeeded in building upon Franklin's discovery a whole superstructure of accurate knowledge. They have measured the quantity of electricity generated by the cloud, the rate at which it is generated, the electrical pressure or voltage produced, and from these measurements it has proved possible to draw a number of very interesting and far-reaching conclusions.

Let me begin by describing some of these measurements and their results. First of all, the quantity of electricity stored up in the average thunder-cloud. This we find to be surprisingly small. Its value is about twenty coulombs of electricity, which at ordinary lighting pressure we could buy for 1/200 of a cent. It is the same quantity as flows through an ordinary lamp bulb in rather less than a minute. The thunder-cloud can generate this small quantity in five seconds. It holds it for a while, increasing it slightly against leakage and other losses incident to such a machine, and then is forced to let it disappear in the form of a lightning flash. Immediately after the flash it regenerates the electrical charge once more. This small quantity of electricity is, however, stored at a pressure of between one and five billion volts, about 100 times greater than the pressure developed in the biggest electrical set-ups yet devised by man. It is the enormous pressure which makes the discharge of such a small quantity of electricity so spectacular, so important and so dangerous.

While the visible effects of a thunderstorm, the flashes themselves, take place in a very short time, it must be remembered that the thunder-cloud machine is continuously generating electricity at this high pressure in the intervals between the flashes. Measurements show that the electrical energy continuously generated by a single cloud is about

three million kilowatts, three times greater than that obtained from the Niagara Falls and sufficient to supply a modern city of ten million inhabitants with light and power for the whole hour or so during which the storm is active.

The motive power behind this great electrical machine is the wind, which blows up from below the cloud with tremendous force, like a gale up a chimney. The power of the wind can be judged from the facts that this upward current of air supports the cloud with an average weight of about 300,000 tons of water, and on occasions can hold up hailstones of considerable size.

The number of thunder-storms occurring over the whole surface of the earth is very great. It amounts to sixteen million storms per year, or 44,000 every day. If you could take a quick glance around the globe at this particular moment of time, you would see approximately 2,000 thunder-storms busily at work. While this number may vary slightly from second to second, your count would be much the same at any moment at all in the course of the year. To get the total world electrical output from thunder-storms we must therefore multiply the figures given for a single thunder-storm by a factor of 2,000. This amounts to a total output of ten billion kilowatts continuously being generated by the world's thunder-storms, an amount which is rather greater than one ten thousandth part of the enormous energy which the sun gives to the earth in the form of light and heat.

The way in which thunder-storm energy is spent is of considerable interest, for the amount involved is so great that quite a small portion of it may produce an important effect. Tracing out the various activities of thunder-storms may carry one in this way into regions very far removed from the storm itself. I can, however, deal here with only one of these sidelines and that the most obvious. About half of the energy is spent in the form of lightning flashes, 100 of which occur in every second over the whole earth. The lightning flash is of course a gigantic electrical spark passing either from one part of the cloud to another or between the cloud and the ground. The flashes which I shall proceed to discuss with you are those taking place between the cloud and the ground.

The idea that a flash is a continuous spark, enduring for a second or more, is an optical illusion, for the lightning spark is really made up of a series of separate sparks which are called the separate strokes of the discharge. The number of strokes making up the whole flash may vary from one to ten or twenty, and the composite nature of the flash is responsible for the flicker which the eye sometimes observes. It is generally the first of the series of strokes which is the most intense and which carries the branches or forks. The branches are practically always directed downwards from the cloud, like the roots of a tree. Each stroke so far examined has been found to be itself a double discharge and to consist of two component strokes traveling in opposite directions.

Let me describe what the photographs taken in South Africa with special cameras tell us about the first and most important stroke of the series. If your eye were as quick as these cameras, you would first of all see a little tongue of light stretch down about fifty yards from the cloud in the direction of the ground. The light pauses, fades out for one ten-thousandth part of a second. Then the tongue reappears and stretches for another fifty yards. Another fade-out, another stretch, and so on. The process continues till the tongue of light reaches the ground. As it moves downward the tongue may sometimes form branches so that while one tongue proceeds to the ground other branching tongues travel outwards and downwards into the air. We call the tongue the "leader" to the stroke.

The instant the leader touches the ground the second or main part of the stroke begins. A brilliant flame sweeps upward from the ground towards the cloud, retracing the path blazed by the leader. As it sweeps upward it also spreads outward along the branches if any of these have been blazed by the leader. The first leader, on account of its pauses, takes a comparatively long time to reach the ground, about a hundredth of a second in many cases. The main stroke is much faster and traverses the same distance in about fifty millionths of a second. In the case of the second and succeeding strokes of the flash the procedure is slightly different. The leaders now exhibit no pauses but proceed steadily to the ground along the same track as the leader of the first stroke of the series. The main flame-like stroke leaps up in the same way as the first main stroke but with less development of light and heat.

As far as the majority of lightning strokes to ground are concerned, then, it appears that the first effect is the downward blazing of a trail from cloud to ground. The second is the much more rapid and intense illumination of this trail by a flame-like spark traveling back along the same path. The process may repeat itself in the same general way after short intervals, until the supply of electrical energy is exhausted and completely converted into the light and heat of lightning and the sound waves, developed as a result of this sudden heating, which we call thunder.

The full explanation of these events is involved and more information must be obtained before we can feel that the mechanism responsible for them is fully understood. It is hoped, however, that when this new information is combined with the experiments on artificial lightning made in the great research laboratories of the United States and elsewhere we may at last be in a position to understand completely the manner in which these gigantic electric sparks are initiated.

Such an understanding should be of aid in the development of still better methods of protecting life and property against the effects of lightning. It should also enable us to apply the knowledge gained from sparks several miles long to the smaller ones which are of such importance to our every-day life. Even if we can not do much to tame the lightning we may learn from it how to design better sparkplugs for our automobiles.

THE COOLING OF THE EARTH AS A PROBLEM IN METALLURGY

By Dr. H. E. STAUSS

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THEORIES of the origin and character of the earth are numerous, but most agree in assuming, in analogy with the present condition of the sun, that the earth was once molten, and that it has cooled, at least on the surface, to produce the earth as we know it to-day. What the interior of the earth may be, liquid or solid, no one knows. We may be living on the crust of a ball of fire, or we may be living on the surface of a solid sphere. The data of seismology are interpreted to mean that the earth consists of several concentric shells. The only clues to the character of these shells are their elastic constants, as deduced from the propagation of earthquake waves, and the average density of the earth. The interpretation of the clues is complicated by the unknown effects of temperature and pressure inside the earth. The average density is about two thirds that of nickel. The concentric shells of the seismologists are thought to be a center core of liquid, with about half the radius of the earth, a shell of the rock dunite forming most of the rest of the earth, and then a thin superficial layer of granite lying under the outermost strata known to geologists.

Since the earth is a cooling body, its behavior during cooling and solidification is of extreme interest to science, but unfortunately that behavior is as yet little more than a matter of speculation. In view of the fact that up to the present the science of metallurgy has given more study to the cooling and solidification of molten liquids than have other sciences, it is interesting to apply the results of metallurgy to the cooling of the earth, without trying to correlate them closely with other theories and without attempting to determine whether the phenomena to be expected have already occurred or are still to happen. The application will suffer, as do all other speculations regarding the interior of the earth, from ignorance of the effects of combined high pressures and high temperatures. These effects will be ignored, as will such refinements as radioactivity and the transmutation of matter and energy.

There are about ninety known terrestrial elements, most of them metals or metalloids. Any metallurgist confronted with the problem of studying the equilibrium conditions of the ninety-odd elements would be driven to despair. Binary systems of metals are his usual task; occasionally he tackles the complexity of ternary systems. Quaternary systems are not studied in detail. Yet nature has mixed the ninety-odd elements, and any adequate study of what she has done must follow her. At present what she may have done can only be considered sketchily in the light of the behavior of the simpler systems.

Probably the best starting-point for the metallurgical study is the earth condensed to liquid, hot enough still to have a metallic atmosphere. As the earth cooled further, condensation proceeded, and at the same time profound internal changes were likely to occur. It is well known that not all liquids are mutually miscible in all proportions, oil and water being the best-known examples. Liquid metals are no exception to the rule. For example, liquid zinc and liquid lead,

which are miscible at elevated temperatures, separate at lower temperatures and go their independent ways until they freeze into two distinct metals. The mixture of 50 per cent. zinc and 50 per cent. lead, by weight, for instance, is a single liquid above 900° C. (1650° F.), but when it has cooled to 900° C., it separates into two layers, although freezing does not begin to occur until 419° C. (786° F.). If the starting-point of this discussion has been taken sufficiently far back, the temperature of the earth was high enough to maintain all the elements in one homogeneous liquid, except as gravity may have affected the distribution of density. But as the earth cooled, it may well have separated into two or more liquids. If such a change did occur, it had a profound influence on the earth. The heavier liquids fell towards the center, the lighter ones rose towards the surface. The redistribution of mass changed the radius of gyration of the earth, and hence its rate of rotation and its day, shortening the latter. The changes presumably would be slow, but they conceivably might be cataclysmically swift. Even after the earth had cooled far enough to have a crust and to support life, such internal rearrangements could occur, with tremendous effect upon the surface and the organisms on the surface; and the changes may have occurred not once, but several times. Such possibilities indicate the complexity of the problem of the reconstruction of the earth's past.

While the earth was cooling and while it was still entirely liquid, chemical reactions began to occur, those which resulted in the formation of compounds, stable at high temperatures, either as solids or as liquids. These compounds separated from the matrix, and the lighter ones floated to the surface to form the crust. Dissolved oxygen reacted to form many of the refractory oxides—aluminum oxide, silicon dioxide, beryllium oxide, magnesium oxide, ferric oxide. At the appropriate temperatures some of these compounds reacted among themselves. Many oxides, for example, combined with silicon dioxide to form low-fusing silicates that rose to the surface as liquids. Phosphorus might ultimately have floated to the surface in liquid phosphates. Such reactions at high temperatures in molten metals are in common use in the melting-room to remove traces of undesirable elements, and there can be little doubt that they would occur during the cooling of the earth. In fact, the earth's crust is almost entirely such products. Silicates are wide-spread. Aluminum and iron are the most common metals. Many of the primitive rocks are glasses —silicates in composition. Our very outermost crust is the result of the physical and chemical reactions that have since occurred to these primitive rocks.

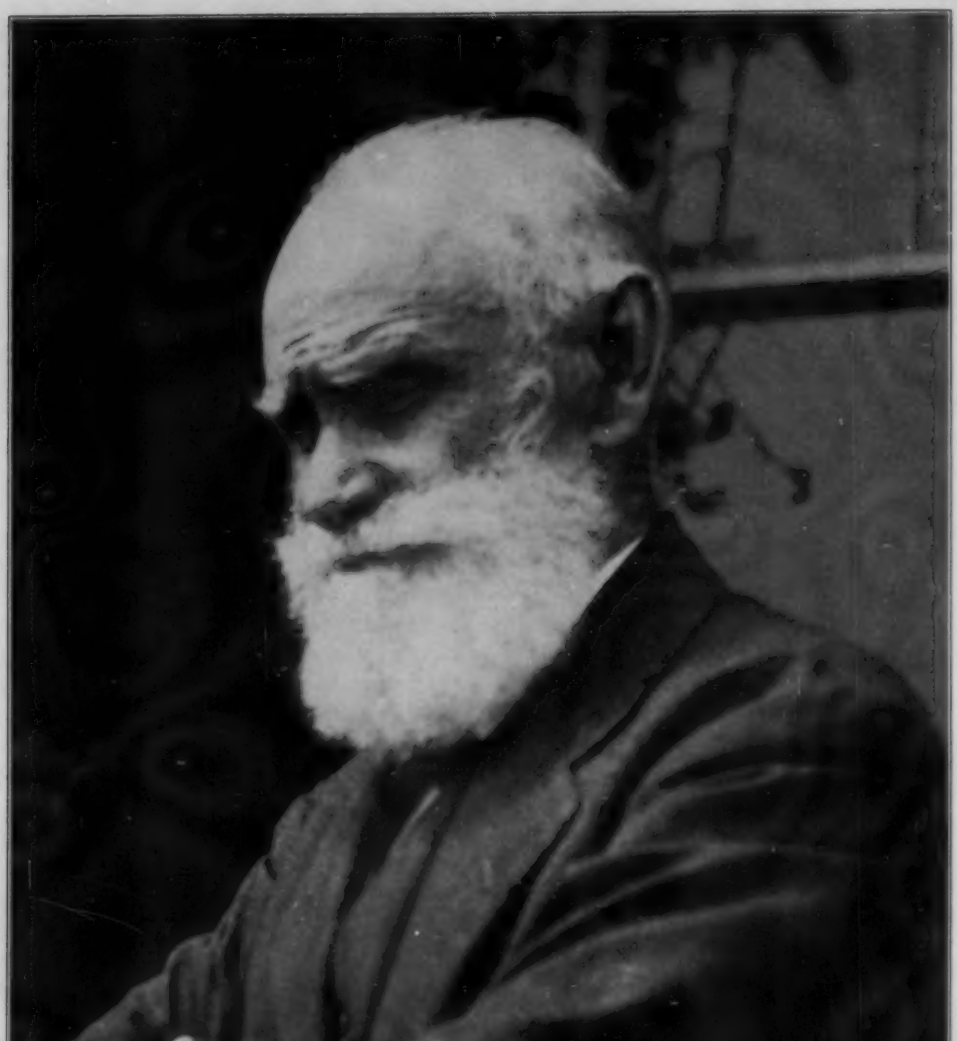
While the earth was yet a molten ball, it no doubt contained in solution some of the gaseous elements. In most cases, the ability of a molten metal to dissolve gases increases as the temperature rises; or, in other words, as the temperature of a molten metal falls, the solubility of gases decreases and the gases begin to be liberated. At the freezing-point the decrease in solubility is discontinuous, and practically all the dissolved gas is rejected. The earth's atmosphere can be explained as being composed of the gases once dissolved in the molten earth and rejected by its parts upon their cooling and freezing. Nitrogen, being relatively inert, has escaped to form most of the earth's atmosphere. Oxygen and the other chemically active gases have been mostly trapped in chemical compounds —hydrogen and oxygen together, in direct chemical reaction, in water, oxygen in many oxides, chlorine in sodium chloride.

When the temperature of the earth

had cooled sufficiently, crystals began to precipitate, both in the liquid metal and in the liquid compounds which had not solidified as glasses. Where in the earth's mass precipitation occurred depended upon both the temperature and the composition of each layer. Heavy, high-melting constituents at the center might freeze out before lighter, lower-melting ones nearer the surface, if the temperature gradient in the interior was not too steep. If the gradient was great, solidification would begin near the surface. In general, the solid crystals were more dense than the liquid matrix and sank as they formed until they encountered their own densities. Here, however, they might encounter higher temperatures again, and begin to melt. Any such occurrences, of course, led to great migrations of material in the earth's interior, disturbing its rotation, and also led towards a flattening of the temperature gradient in the earth's interior. When conditions had come to such a pass that at any position crystallization could proceed without interruptions by melting, it is unlikely that uniform concentric shells were formed. A slowly cooling alloy, such as we are assuming all or part of the earth to be, crystallizes in branching dendrites, in structure appearing like the well-known forms of snowflakes. The earlier freezing portions form the dendrites, the later freezing parts fill the interstices as liquid, and finally freeze in them. For a period of time freezing is primarily along the dendrites. Thus it is very possible that at one time the interior of the earth was like a ball of liquid, reinforced with great ribs of crystals.

While freezing occurred, great quantities of heat were released. If this heat was not liberated uniformly over the period during which it was available, the history of life on the outer crust must have fluctuated with the changes in the rate of release of energy. The crust acts as a great insulating blanket on the interior of the earth, but its temperature would vary somewhat to permit the dissipation into space of varying quantities of heat. By its blanketing action it would force the temperature beneath it to rise when heat was liberated; and this rise would melt the base of the crust, thinning the latter; and thus, by reducing the thickness of the insulation, raising the temperature of the outer surface. Climatic fluctuations, such as the great ice ages, may well have resulted from the manner of the cooling of the earth.

The behavior of the gases dissolved in the molten interior deserves somewhat more attention than it has received so far. When gas is rejected in a molten liquid, it rises to the top and escapes if possible. When the exterior of the metal is already frozen solid, it collects as a bubble in the yet molten part. In the melting-room many a bar is found to contain these bubbles or "gas holes." Once the surface of the earth was solidified, rejected gases could no longer escape harmlessly to the surface. The part that could drifted upward to find lodging under the solid crust, possibly to leak out slowly through minor fractures in the crust, conceivably to push up the bulges that we call continents. However, when too much gas was liberated, the bubbles might be subject to extreme pressures, and might eventually break through the crust at a weak spot, as a volcano, for example. The gases to be expected from metallurgy are predominately oxygen and hydrogen, but these two react readily to release steam from the melt, and oxygen will react with dissolved carbon to release carbon monoxide or dioxide. In actual fact volcanoes release vast quantities of steam. It is possible that they are exterior openings of the vents connecting the earth's surface with the still solidifying interior.



IVAN PETROVITCH PAVLOV

THE PROGRESS OF SCIENCE

IVAN PETROVITCH PAVLOV

On the 19th of February, 1916, the *Lancet, British Medical Journal* and *Journal of the American Medical Association* all carried detailed obituaries of Ivan Petrovitch Pavlov, confusion having arisen over the death of E. V. Pavlov, the surgeon. All three notices had been prepared by distinguished physiologists, and it is significant that Pavlov's work on gastric physiology was described by each one; but the notice in the *Lancet* makes no reference at all to conditioned reflexes, and in the other two notices they are mentioned briefly and in the vaguest terms. Pavlov's epoch-making studies on the activities of the cerebral cortex, begun about 1902, were practically unknown outside of Russia until Gleb van Anrep brought tidings of the new work to England just before the war; Pavlov himself had actually made a preliminary announcement in London in 1906 and again at Gröningen in 1913, but not until Bayliss' "General Physiology" was published in 1917 were conditioned reflexes generally understood. The English-speaking world waited, moreover, until 1927–28 for the Anrep and the Gantt translations of Pavlov's lectures, which for the first time gave adequate information concerning Pavlov's views and the experimental data upon which they were based.

Pavlov's death, which was authoritatively announced from Moscow on February 27, 1936, brings with it a sense of deep personal loss to physiologists the world over, and especially to those who had the good fortune to attend the Fifteenth International Congress in Russia last August. There one saw in his own surroundings the man who had already become a legendary figure. One visited the three laboratories which he personally directed, one witnessed his apotheosis by a proud and generous people—a form of recognition more sumptuous and elaborate than had ever before been accorded by a government to a scientific man. Pavlov had been recently ill, but the Fates seemed to have decreed that he should live until the Physiological Congress was over. Only a week before the great gathering at Leningrad, Pavlov and one of his sons made a surprise trip to London to attend the second International Neurological Congress, and he was able to return to Leningrad only a few days before his own congress commenced. Both in London and in Leningrad he was unbelievably active, reading addresses and papers himself, attending the scientific sessions, being host to delegates, entertaining at luncheons and dinners, and finally presiding at that memorable feast at Detskoye Selo, the official dinner of the Physiological Congress held in the ancient banqueting halls of the Catherine Palace; it was attended by some 1,600 delegates. When Pavlov appeared on that memorable occasion he received a stirring ovation which continued, almost without interruption, until the next day.

Ivan Petrovitch Pavlov, the first son of a village priest, Peter Dimitrievitch Pavlov, of the district of Rjazan in Russia, was born on September 14, 1849. He received his early education from a local school and, later, intending to take holy orders, he entered a neighboring theological seminary. At the age of sixteen there fell into his hands a copy of the new Russian translation of "The Physiology of Common Life," by George Henry Lewes, that versatile character who played so large a part in the life of George Eliot. Lewes's book contains several remarkable chapters entitled, "Feeling and Thinking," "The Mind

and the Brain," "Our Senses and Sensations," and "Sleep and Dreams"; these chapters form a highly important landmark in the history of physiological psychology, not only because they stimulated the young Pavlov (and incidentally also William James), but because they represent one of the earliest objective treatises on the functions of the cerebral hemispheres. Under the stimulus of this book, a copy of which he kept always beside him as a *comes viae vitaeque*, Pavlov left theology and determined to follow biological science as his career. It is thus interesting to realize that the crucial stimulus of Pavlov's life career came from England.

Other details of Pavlov's life are well known, thanks to the excellent biographical sketch published in 1929 by Gantt in his translation of Pavlov's lectures. He entered the University of St. Petersburg in 1870; in 1878 he was first heard from outside of Russia through a series of papers on the conditions affecting the blood pressure (unanesthetized dogs). In 1879 there followed three papers on the pancreas, one describing his method —similar to that of de Graaf—for making a pancreatic fistula. Not until 1889, however, did one of Pavlov's pupils describe (*Centralbl. f. Physiol.*, 3: 113–114, 1889) the new method for studying uncontaminated gastric juice. Fistulous openings were made in the stomach and after a prolonged period of careful nursing care, by Madame Pavlov (Serafima Karchevokaya, whom he married in 1880 and who survives him) and his four children, the animal was restored to health. Then followed a series of experiments on sham feeding and analysis of psychic secretion, which culminated in 1904 in his receiving the Nobel prize.

That Pavlov should after 1902 have turned his attention to the nervous system was logical in view of the direction which his work on digestion had taken. To use his own words (Gantt ed., p. 37): "For many years previously I had been working on the digestive glands. I had studied carefully and in detail all the conditions of their activity. Naturally I could not leave them without considering the so-called psychical stimulation of the salivary glands, *i.e.*, the flow of saliva in the hungry animal or person at the sight of food or during talk about it or even at the thought of it. Furthermore, I myself had demonstrated a psychical excitation of the gastric glands." The conditioned reflex was the direct outcome of these studies, but it is sometimes not appreciated that E. L. Thorndike, Franz and Yerkes in this country undertook studies of a similar character at about this time, and Pavlov in more than one place has referred to their priority. Thus Pavlov states (*ibid.*, p. 40): "Some years after the beginning of the work with our new method I learned that somewhat similar experiments on animals had been performed in America, and indeed not by physiologists but by psychologists. Thereupon, I studied in more detail the American publications, and now I must acknowledge that the honour of having made the first steps along this path belongs to E. L. Thorndike. By two or three years his experiments preceded ours and his book, "Animal Intelligence—an Experimental Study of the Association Processes in Animals," 1898, must be considered as a classic, both for its bold outlook on an immense task and for the accuracy of its results."

In a sense Pavlov was an unsophisticated child of nature. Naïve, direct, untouched by convention or prejudice, he set out to describe the things he saw in the boldest terms. In addition he had the genius to devise a new form of experiment which was adequate for analysis of a problem which no one, save Thorndike, had yet approached. His philosophy had little profundity, and yet by its very simplicity and directness it has caused men to think in new terms. Pavlov was guilty of over-simplifying an

extraordinarily complex subject, but as a first approximation in a field where doubt, mystery and prejudice reigned before, it had the outstanding virtues of a new and compelling hypothesis: it crystallized a great problem and clearly indicated the path to be followed for its solution.

Sherrington's prophetic remarks made in 1905 have fresh significance to-day ("Integrative Action of the Nervous System," p. 307): "New methods of promise seem to me those lately followed by Franz, Thorndike, Yerkes and others; for instance, the influence of experimental lesions of the cortex on skilled actions recently and individually, *i.e.*, experientially, acquired. Despite a protest ably voiced by v. Uexküll, comparative psychology seems not only a possible experimental science but an existent one. By combining methods of comparative psychology (*e.g.*, the labyrinth test) with the methods of experimental physiology, investigation may be expected ere long to furnish new data of importance toward the knowledge of movement as an outcome of the working of the brain." At the time these words were uttered, Pavlov had also begun to vindicate them in a brilliant manner, and he lived to carry the work further than any other investigator in the field.

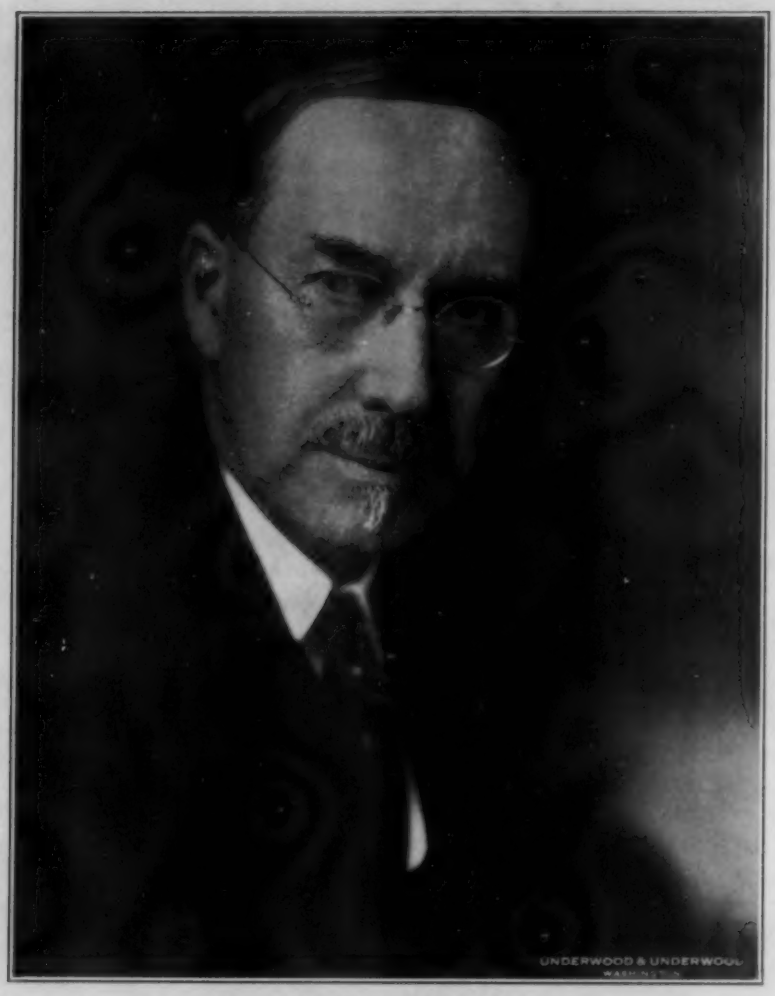
J. F. F.

DR. MERRIAM'S CONTRIBUTIONS TO THE DEVELOPMENT OF VERTEBRATE PALEONTOLOGY ON THE PACIFIC COAST[1]

Dr. Merriam is both author and interpreter of an epic poem of unsurpassed grandeur. This poem is not written in verse but in the sober language of science. It is the epic of the history of vertebrate life on the Pacific Coast, and the story is told in a long series of publications, chiefly in the bulletins of the Department of Geology of the University of California, but of late years also in the paleontological memoirs and papers of the Carnegie Institution of Washington, D. C. More than sixty localities scattered over California and the adjoining states have yielded the historical documents, in the shape of fossilized animal and plant remains, upon which this great epic has been built up. The brief moments at our disposal this evening permit us to glance at only a few of the scenes of this gigantic drama, which is still winding its slow way along after some four hundred and fifty million years of continuous performance.

Let us pass over the earlier chapters, which are indeed not nearly so well represented on the Pacific coast as they are in the East, and let us stop for a moment in the middle Triassic Period, about one hundred and sixty million years ago. The records of this period are preserved in the limestones of what is now the West Humboldt Range in Nevada. At that time the broad sea covered the place where now the Rockies rear their peaks, and in the long swell of a sunny Pacific day strange creatures disport themselves. Some of them are veritable sea serpents about thirty feet long. They look at first like long-snouted but slender dolphins. Dr. Merriam, our paleontological Dante, tells us, however, that they are called ichthyosaurs, or fish-lizards, but that in truth they are neither fish nor lizards nor any combination of the two; but that they are descendants of land-living reptiles of still earlier ages, reptiles which had been tempted into the sea by the abundance of food and had gradually changed their legs into paddles, their tails into rudders. But if you wish to learn more about the origin, rise and decline of this race of sea monsters, I refer you to Dr. Merriam's monograph on "Triassic Ichthyosauria" in the Memoirs of the University of California,

[1] Address upon presentation of Dr. John C. Merriam for the Gold Medal of the American Institute, February 6, 1936.



DR. JOHN C. MERRIAM
PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

Volume I, 1908. This work in my opinion should be one of the major documents of all students of evolution.

After the disappearance of the Triassic ichthyosaurs scores of millions of years pass by, the ponderous dinosaurs appear, live their brief day and trample each other to death in the last waterholes, as the Rocky Mountains rise above sea level and the low swampy coast lands are gradually raised into mountains and grassy plains.

New actors then come on the stage, the varied placental mammals of the Upper Eocene times, some forty-odd millions of years ago, and their successors of the Lower Oligocene a few million years later. As yet the fossil records of these horizons, which have been recently discovered in localities near Death Valley, California, are rather scanty, but as described by Dr. Chester Stock they are of great importance because they serve to tie in the lower levels of the California mammalian sequence with certain faunas of corresponding age found in the Rocky Mountain basins of Wyoming and on the ancient plains of Colorado, Nebraska and South Dakota. And just as the archeologists endeavor to date their newer dis-

coveries in Asia Minor by comparison with the sequence of cultures already well known in Egypt, so are the paleontologists under Dr. Merriam's leadership slowly correlating the torn earlier chapters of the mammalian life record of the Great Basin of California with better known records of the Rocky Mountain and Great Plains regions of the East.

More millions of years roll on and we come to the far more abundant records entombed in the great formations of the John Day Basin in Oregon, of Upper Oligocene age, followed by the Mascall of Miocene age and the Rattlesnake of Pliocene times. Far to the south, in what is now the Mohave Desert, the story is carried into later chapters of the Upper Miocene and Pliocene by thousands of fragments, which Dr. Merriam and his collaborators are still diligently studying and describing. During these long ages the ordinary business of living and breeding, of feeding, fighting and dying, was eagerly carried on by countless herds of animals, especially the three-toed horses, antelopes with bizarre and twisted horns, rhinoceroses, mastodonts, primitive elephants and others with strange names. Nor were their pursuers, the dogs and bear-dogs of assorted sizes and shapes, the saber-toothed cats, the jaguar-like cats and many other carnivores, in their attacks upon the frightened herbivores any less stealthy or persistent or ferocious than are their modern relatives.

At intervals the face of nature would be convulsed and volcanoes would pour out vast suffocation and destruction upon the plant and animal worlds. But ever and again after things had quieted down, new settlers would come in and the slow preparations for the next holocaust would be resumed.

At last the Ice Age settled slowly down upon Europe and even the eastern United States, but California, true to its traditions, maintained its famous climate and was the refuge of species that could not endure the rigors of the East. Near Los Angeles beneficent nature, evidently with Dr. Merriam in mind, arranged a most ingenious series of traps in the form of pits filled with asphalt, in which she patiently collected thousands of parts of saber-toothed tigers and dire wolves trapped with their victims, the giant ground sloths. This section of the epic is set forth in the monograph on "The Felidae of Rancho La Brea" by John C. Merriam and Chester Stock.

Near the end of the Pleistocene chapter of the epic great caverns were formed in the ancient marine limestones, and into these caverns crept a strange assortment of woolly beasts, perhaps related to the musk-ox, which have been celebrated by Dr. Merriam, Dr. Sinclair and Mr. Furlong.

But during all the later ages while Dr. Merriam watched and sang the drama of vertebrate evolution, he was steadily searching for traces of nature's greatest devastator, *Homo sapiens*. At last some of his sleuths have discovered near Folsom, New Mexico, and in other localities, an abundance of peculiar flint points, with other evidence that these early Americans of perhaps some twelve thousand years ago were busily engaged in the congenial task of exterminating a contemporary species of American bison.

Perhaps it was the vision of eternal creation, carnage and destruction, the mystery of the emergence of new forms, and the inner beauty that he sees through fossil bones, which have reacted to make Dr. Merriam one of the world's greatest conservationists. To him, and to his friend, Madison Grant, future generations of Americans will owe the arrest of the depredations of their species upon the noble sequoias.

Now I have unfortunately left myself but a moment to speak of all the mighty residue of Dr. Merriam's activities. But what can one do in the case of a man who has literally made the universe his laboratory? How could I tell adequately

of the work of the great astronomic observatory at Mount Wilson, of the magnetic survey of the world in the good ship *Carnegie*, of the oceanographic laboratories at Woods Hole and Bermuda, of the Station for Experimental Evolution at Cold Spring Harbor, of the Carnegie Institution Laboratory for the Study of Embryology in Baltimore, or of many other important research projects which have been maintained by the Carnegie Institution of Washington under the presidency of Dr. Merriam? Or how could I summarize in a few minutes his highly constructive discussions of the rôle of science in human affairs?

Let it be enough to say that his colleagues and fellow citizens everywhere appreciate his far-sighted and judicious labors in their behalf. They recognize their great debt of gratitude to him and hold him in the highest honor and affection.

WILLIAM KING GREGORY

OPENING OF THE NEW YORK MUSEUM OF SCIENCE AND INDUSTRY AT THE ROCKEFELLER CENTER

HERALDED with a spectacular scientific demonstration, which spanned the Atlantic Ocean and reached across the continent in the flash of a few seconds, and hailed by world-famous men of science as an event of epoch-making importance, the New York Museum of Science and Industry opened the doors of its permanent home in the RCA Building of Rockefeller Center on February 11.

Here, against a background of exhibits showing their evolutionary progress, are the newest developments of the scientific and industrial worlds, displayed in such fashion as to present before the observer's eyes a striking picture of the mechanics of everyday life in actual operation. Thus the visitor pushes buttons, pulls levers and turns cranks and sets in motion generally the wheels of the machinery underlying the mysteries of transportation, communication, electrotechnology and numerous other of the foundations on which the modern world is built.

For the Museum of Science and Industry is preeminently a place where things move and, even better, a place where people themselves make things move, thus staging their own demonstration. In practically every other kind of museum, the visitor's only part is to stand and look, to walk around and look again. In this unique museum, one of less than half a dozen such in the entire world, he puts on his own show and enjoys himself thoroughly in so doing.

Of the eleven permanent divisions of the museum—communications, aviation, highway transportation, marine transportation, railroad transportation, power, textiles, housing, machine tools, electro-technology and food—every one of them except the housing section includes innumerable moving exhibits, either in full size or in scale models. In the aviation division, for example, one of the main attractions is the so-called "pilot trainer"—the airplane cockpit into which any one may climb and, operating the dials on the instrument board in front of him, maneuver the machine of which he is temporarily in sole control, this way and that—in any direction except off the ground.

In the transportation section, the visitor can start the wheels of locomotives turning, operate railroad signals and flash important lights—all in miniature models from the early crude designs of locomotives to the stream-lined mogul of to-day. The communications section offers a practical demonstration of ship-to-shore radio communication by operating the apparatus, in miniature, by which a ship determines its position in relation to lighthouses sending out radio

PROFESSOR ALBERT EINSTEIN AND DR. FRANK B. JEWETT
AT THE OPENING EXERCISES IN THE ROCKEFELLER CENTER. DR. JEWETT IS PRESIDENT OF THE BOARD OF TRUSTEES OF THE NEW YORK MUSEUM OF SCIENCE AND INDUSTRY.

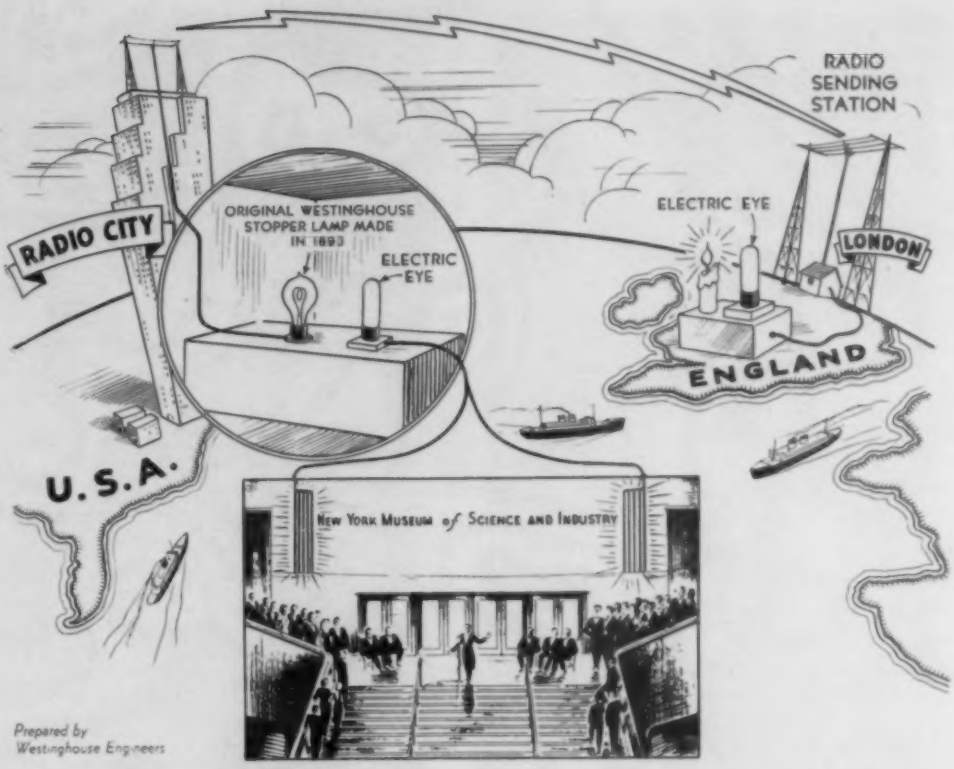
signals. By pressing a button and turning a knob, one maneuvers the tiny radio receiving loop on the prow of a small vessel into the proper position to catch the signals from the lighthouse which flashes in the distance. An exhibit which demonstrates each step of the dial telephone system, synchronized to each motion made as the investigator puts through a call on an actual dial telephone, is another favorite plaything with museum visitors.

The electro-technology division, with its moving exhibits demonstrating magnetism, the generation of electric current, high frequency transmission, the principle of radio tuning and a host of other "miracles" in this highly technical field, draws crowds to watch the gadgets whirl around and illustrate for them the mysterious whys and wherefores of many things they take for granted in the ordinary routine of living. Modern machines used in various types of industrial plants—automobile factories, iron and steel works, power plants, refrigerating plants and the like—go through their paces for the daily visitors likewise.

In addition to the permanent exhibits, a series of special exhibits will be seen at the museum, arranged by outstanding research laboratories and industrial concerns as occasion arises to show something of unusual interest or some new development along scientific lines. In this way, the museum will keep the public informed in up-to-the-minute fashion in regard to happenings in the fields it covers.

At the present time, the special exhibits are four in number, assembled by the laboratories of the Eastman Kodak Company, the General Electric Company, the Goodrich Rubber Company and the Bell Telephone Company. The first of these offers the latest developments in photography, color photography, radiography, etc., with much of practical interest to the amateur photographer as well as the demonstration of scientific principles. In the second, a favorite attraction, among many others, is the new powerful magnetic alloy, capable of lifting sixty times its own weight. The Goodrich Company permits visitors to push a button and set in motion the de-icer, the device by which the wings of the modern airplane are kept free of ice when flying

SIR WILLIAM BRAGG AT THE DESK OF MICHAEL FARADAY IN THE ROYAL INSTITUTION OF GREAT BRITAIN. AT THE RIGHT IS THE CANDLE WHICH TOOK PART IN LIGHTING THE MUSEUM ON THE OPENING NIGHT.



THE PATH TRAVELED BY THE ELECTRIC IMPULSE FROM LONDON

THE IMPULSE SET IN MOTION BY THE CANDLE FLAME, LIT BY A MATCH STRUCK BY SIR WILLIAM BRAGG, DIRECTOR OF THE ROYAL INSTITUTION OF GREAT BRITAIN, WAS PICKED UP BY A PHOTO-ELECTRIC CELL AND RELAYED ACROSS THE OCEAN, WHERE A SECOND PHOTOELECTRIC CELL RECEIVED IT AND CAUSED IT TO LIGHT THE 50-YEAR-OLD ORIGINAL INCANDESCENT LAMP. THE LATTER TURNED ON THE HIGH INTENSITY LAMPS BORDERING THE ENTRANCE OF THE MUSEUM.

through low temperatures, while the Bell Telephone Laboratory has set up a mechanism which affords one the unique experience of listening to himself talk on the telephone.

All this is in line with the expressed purpose and wish of the founder of the museum—Henry R. Towne, whose will brought into existence and endowed the institution in 1927. It was Mr. Towne's feeling, as set down in the will, that while "the United States is the greatest industrial nation of the world, with organized industries exceling those of all other countries in magnitude and efficiency, our national achievements in this great field are unrepresented by any permanent collection of examples illustrative of their history and growth. We do not possess any permanent exposition of American achievements in the peaceful arts, which great groups include the arts of agriculture and animal industry; of forestry and woodworking; of mining and metallurgy; of transportation and communication; of engineering and architecture; of industrial chemistry; of electrical mechanism; of aeronautics; of the metal, textile and building trades, and of the innumerable subdivisions of all these, including their products, processes and implements."

Other important groups interested in maintaining and constantly expanding

the scope of the museum so that it may most successfully carry out its program of presenting to the public a continuing and dramatic demonstration of important scientific developments as they take place are the Rockefeller Foundation, the New York Foundation and the Carnegie Corporation.

The high point in the elaborate program which dedicated the new home of the museum was the lighting in the museum of a bank of forty new mercury lamps, the last development in artificial lighting, as the result of a candle flame lit in London. Seated at the desk of Michael Faraday, where Faraday worked out his epochal experiments in electromagnetism, Sir William Bragg, director of the Royal Institution of Great Britain, struck a match and lit a candle, the sound plainly audible on the radio to the audience of several thousand gathered in the museum. A photoelectric cell on the same desk picked up the rays and sent out an impulse over the Atlantic. In New York the impulse was filtered from Sir William's speaking voice and sent to another photoelectric cell in the museum. There it caused to glow for the first time in fifty years the original incandescent lamp manufactured by the Westinghouse Company and taken from the Westinghouse Museum for the occasion, and, in turn, the old lamp turned on the bank of mercury lamps.

Professor Albert Einstein took part in the dedication program, other speakers being Dr. Robert A. Millikan, Nobel laureate in physics, Dr. Irving Langmuir, Nobel laureate in chemistry, Amelia Earhart, Mayor Fiorello La Guardia and Dr. Frank B. Jewett, president of the Board of Trustees of the New York Museum of Science and Industry.

M. C. M.

PHOTOGRAPHY OF METEOR SPECTRA

THERE is no branch of astronomical photography that has a greater appeal to the sporting instinct than the photography of meteor spectra. This is because no one can predict when, or in what part of the sky, a bright meteor will appear, and when it does appear the whole phenomenon rarely lasts longer than two or three seconds. A program of meteor photography thus resolves itself into something very much like a fishing expedition, where the observer sets up a camera instead of throwing out a line and then leaves the shutter open, hoping that a bright meteor will cross that part of the sky towards which the camera is directed. The thrill of securing a particularly fine meteor spectrum is also closely akin to the elation experienced in landing a fish of record weight.

The best camera to use for this purpose is a small one having a lens with a focal length lying in the range between four and twelve inches and a speed ratio F 4.5. Nominally faster lenses have relatively poor definition in the outer part of the field and so are unsuitable. A prism with refracting angle between 25 and 35 degrees is mounted directly in front of the lens and as close to it as possible. This completes the meteor spectrograph and it only remains to set it up on a stationary mounting and make exposures on the sky which, on a dark moonless night, will average about an hour in length. As a result of recent observational programs it appears that on ordinary nights there is a chance of photographing one meteor spectrum in, roughly, 250 hours' total exposure time. If, however, observations are made during the nights of some of the well-known showers such as the Leonids or Perseids the probability is that a spectrum will be secured for every 10 to 15 hours of exposure time. Nothing better illus-

A METEOR SPECTRUM, TYPE Y

PHOTOGRAPHED ON DECEMBER 15, 1931, AT THE BLUE HILL OBSERVATORY, MASSACHUSETTS. THE METEOR APPEARED ABOUT AS BRIGHT AS JUPITER AND OF AN ORANGE COLOR, LEAVING A TRAIN VISIBLE FOR TEN SECONDS. THE TWO PROMINENT LINES IN THE SPECTRUM ARE GIVEN BY IONIZED CALCIUM. WAVE-LENGTHS IN ANGSTROMS ARE INDICATED.

A METEOR SPECTRUM, TYPE Z

PHOTOGRAPHED ON NOVEMBER 18, 1935, AT THE DUNLAP OBSERVATORY, RICHMOND HILL, ONTARIO. THIS METEOR WAS A BLUE LEONID ALMOST AS BRIGHT AS VENUS, LEAVING A TRAIN THAT REMAINED VISIBLE FOR SEVEN SECONDS. THE MAJORITY OF THE LINES IN THE SPECTRUM ARE GIVEN BY IRON. WAVE-LENGTHS IN ANGSTROMS ARE INDICATED.

trates the part luck plays in meteor photography than the results of a recent program. This comprised 1,350 hours of photographic exposures and on the very last plate loaded into one of the three cameras used the finest meteor spectrum yet secured was photographed.

Up to the present only some forty meteor spectra have been photographed, and over three quarters of this number in the last five years during observational programs planned for this express purpose. Let us see what these photographs reveal.

The most evident fact is that the light of all meteors arises from bright line emission with little or no continuous spectrum. The major part of this consists of the atomic lines of neutral iron, though other elements common in meteorites also appear. Chief among these are calcium, magnesium, manganese, chromium and aluminum. In general it is the ultimate or low temperature lines

of the neutral atom which have been observed, thus giving evidence of a low state of excitation in the luminous meteor vapor. A study of the relative intensities of the iron lines gives evidence of states of excitation corresponding to furnace temperatures in the range 1,700 to 3,000 degrees absolute. We must be careful not to call this the temperature of the iron vapor, as the latter is obviously far from thermodynamical equilibrium and the word temperature has no real meaning in this case.

A further examination of the spectra photographed to date reveals that they may be grouped into two definite classes or types. In the first, designated for convenience Type Y, the H and K lines of ionized calcium are the most prominent feature of the spectrum while the iron lines contribute most of the remainder of the light. In the second, Type Z, the ionized calcium lines are markedly absent and almost all the lines are given by iron. Where the heights of the meteors are known it has been found that meteors of Type Y appear above an altitude of 50 miles while those of Type Z appear below this level. It is significant that this altitude also marks the lower limits of the first ionized layer, the region of brilliant auroral displays, the region of noctilucent clouds and the zone of maximum frequency of meteors and their trains.

The difference in the type of meteor spectra is evidently owing to a difference in the degree or kind of excitation which produces the meteor's luminosity. The necessary energy arises from the high velocity impacts of the air molecules on the meteor which cause first vaporization and then excitation of the meteoric material. It is a well-known fact that the meteors with high geocentric velocity appear at the greatest altitudes. Spectra of Type Y show evidence of higher excitation and probably correspond to the faster meteors. The average excitation of the iron vapor in Type Z is much lower, as would be expected for slower meteors.

The interest of the spectrographic investigation of meteors lies not only in the information it yields concerning the physical processes through which the meteors become visible but also in the assistance it renders in a study of the upper atmosphere which, for the present at least, must be studied indirectly by investigating the properties of phenomena which exist far above the earth's surface. The most important of these are meteors and their trains, the aurora, radio waves and sound waves. It is fast becoming evident that there is far more to learn concerning the upper reaches of the earth's atmosphere than was once thought to be the case. Every clue to its structure and properties is valuable, and the detailed study of meteor spectra is one line of attack that must not be neglected.

PETER M. MILLMAN
DUNLAP OBSERVATORY,
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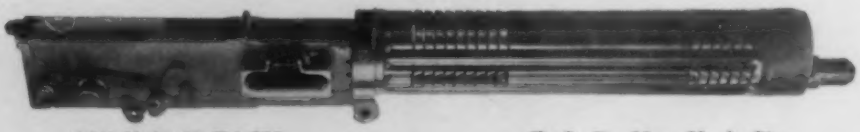

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